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INTERNATIONAL APPLICATION NO.

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PRIORITY DATE CLAIMED

March 15, 1999

TITLE OF INVENTION

SEMICONDUCTOR APPARATUS AND COMMUNICATION APPARATUS

APPLICANT(S) FOR DO/EO/US

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Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to promptly begin national examination procedures (35 U.S.C. 371(f)).
4. ☒ The US has been elected by the expiration of 19 months from the priority date (PCT Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
 - a. ☐ is attached hereto (required only if not communicated by the International Bureau).
 - b. ☒ has been communicated by the International Bureau.
 - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3)).
 - a. ☐ are attached hereto (required only if not communicated by the International Bureau).
 - b. ☐ have been communicated by the International Bureau.
 - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
 - d. ☒ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11 to 20 below concern document(s) or information included:

11. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A **FIRST** preliminary amendment.
14. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
15. ☐ A substitute specification.
16. ☐ A change of power of attorney and/or address letter.
17. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
18. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
19. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
20. ☒ Other items or information:
 - Application Data Sheet
 - 33 Sheets of Formal Drawings (Figs. 1-33)

[illegible]

Docket: 740819-567

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re New National Phase Patent Application of)
Shinji YAMAMOTO et al.)
Japanese Priority Application No. PCT/JP00/01521) Attn: Applications
Japanese Priority Date: March 14, 2000) Branch
For: SEMICONDUCTOR APPARATUS AND)
COMMUNICATION APPARATUS) Date: August 21, 2001

PRELIMINARY AMENDMENT

Honorable Commissioner for Patents
Washington, D.C. 20231

Sir:

Please preliminarily amend the subject application as follows:

IN THE SPECIFICATION:

Please amend page 13, paragraph 5 as follows:

Figs. 30(a) and 30(b) show diagrams each illustrating an adjacent channel leak power which defines the distortion of a digital modulation type power amplifier.

IN THE CLAIMS:

Please cancel claims 7 and 8 and amend claim 14 as follows: Please note that claims 1 and 14 are presented below in their amended form. They are further presented as an Attachment to the Amendment whereby the amendments to the claims are outlined using the conventional method of bracketing and underlining.

1. (Amended) A semiconductor apparatus, comprising, on a same semiconductor substrate:

two or more semiconductor devices to which two or more signals having different frequency ranges are input, respectively; and

a constant current source commonly connected to one ends of the semiconductor devices,

wherein at least one of the semiconductor devices is provided with a control terminal for turning on/off the semiconductor device, and

a constant current value of the constant current source is set to a current value needed for the semiconductor device requiring a lowest distortion among the two or more semiconductor devices.

14. (Amended) The semiconductor apparatus of claim 12,

wherein an inductor is connected to a source of the field effect transistor.

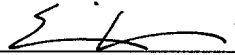
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REMARKS

Claims 7 and 8 have been canceled in accordance with the Article 34 amendment during the international phase. Claim 14 has been amended to correct the claim dependency therein.

Examination on the merits is requested.

Respectfully submitted,



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10/28/2010 3:33:10 PM

VERSION WITH MARKINGS TO SHOW CHANGES MADE

Please amend page 13, paragraph 5 as follows:

[Fig. 30 shows] Figs. 30(a) and 30(b) show diagrams each illustrating an adjacent channel leak power which defines the distortion of a digital modulation type power amplifier.

1. (Amended) A semiconductor apparatus, comprising, on a same semiconductor substrate:

two or more semiconductor devices to which two or more signals having different frequency ranges are input, respectively; and

a constant current source commonly connected to one ends of the semiconductor devices,

wherein at least one of the semiconductor devices is provided with a control terminal for turning on/off the semiconductor device, and

a constant current value of the constant current source is set to a current value needed for the semiconductor device requiring a lowest distortion among the two or more semiconductor devices.

14. (Amended) The semiconductor apparatus of claim 12 [or 13],

wherein an inductor is connected to a source of the field effect transistor.

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DESCRIPTION

SEMICONDUCTOR APPARATUS AND COMMUNICATION APPARATUS

5 TECHNICAL FIELD

The present invention relates to a high frequency semiconductor apparatus and a high frequency communication apparatus for use in radio equipment.

10 BACKGROUND ART

In recent years, active researches have been conducted on dual-band portable telephones using two communication systems for one terminal in order to ensure a sufficient number of communication channels. Since a dual-band portable telephone uses two frequency bands, it requires two of each of the following components that are normally required in a high frequency block: low noise amplifier (Low Noise Amplifier; hereinafter referred to as "LNA"); power amplifier (Power Amplifier; hereinafter referred to as "PA");
15 down-mixer (Down Mixer; hereinafter referred to as "D-Mix"); up-mixer (Up Mixer; hereinafter referred to as "U-Mix"); and local signal generator (Voltage Controlled Oscillator; hereinafter referred to as "VCO"), and it also requires a power switch for operating these components in a time
20 division manner, a reception path switch (hereinafter referred to as "RX-SW") for switching the reception path, a
25

transmission path switch (hereinafter referred to as "TX-SW")
for switching the transmission path, etc.

FIG. 32 illustrates an example of a high frequency
block of a conventional dual-band portable telephone. In FIG.
32, 101 denotes an antenna (hereinafter referred to as "ANT"),
102 denotes a 1-input/4-output antenna switch (hereinafter
referred to as "ANT-SW"), 111 denotes an LNA1, 112 denotes an
LNA2, 121 denotes a D-Mix1, 122 denotes a D-Mix2, 131 denotes
a U-Mix1, 132 denotes a U-Mix2, 141 denotes a PA1, 142
denotes a PA2, 151 denotes a VCO1, 152 denotes a VCO2, 161
denotes an RX-SW, and 162 denotes a TX-SW.

The operation of the high frequency block illustrated
in FIG. 32 will now be described briefly.

The ANT 101 catches radio wave in the air and guides
it into the telephone. The ANT-SW 102 connects one of the
four signal paths RX1, RX2, TX1 and TX2 to the ANT 101.

Next, the operation of the reception side will be
described. The following description will be made with
respect to the signal path RX1 for example. A signal having
a frequency f_{RX1} that is received at the ANT 101 is amplified
by the LNA1 111 and passed to the D-Mix1 121. The VCO1 151
generates a signal having a frequency f_{LO1} , and f_{RX1} and f_{LO1}
are mixed together at the D-Mix1 121, thus being down-
converted to a frequency f_{IF} . At this time, the absolute
value of $f_{RX1} - f_{LO1}$ is f_{IF} . The operation of the LNA2 112 and
the D-Mix2 122 in the signal path RX2 is just as described

above, wherein a frequency f_{RX2} received at the ANT 101 and a frequency f_{LO2} generated by the VCO2 152 are mixed together at the D-Mix2 122, thus being down-converted to the frequency f_{IF} . At this time, the absolute value of $f_{RX2} - f_{LO2}$ is f_{IF} .

5 While the RX-SW 161 switches between signals from the D-Mix1 121 and the D-Mix2 122, the subsequent circuit components after the RX-SW 161 can be shared because the frequencies of the output terminals of the D-Mixes are both f_{IF} .

Next, the operation of the transmission side will be described. The following description will be made with respect to the signal path TX1 for example. While the TX-SW 162 is switched so as to input a signal to either one of the U-Mix1 131 and the U-Mix2 132, the frequency of the signal is f_{MOD} in either case. The VCO1 151 generates a signal having the frequency f_{LO1} , and the signals having the frequencies f_{MOD} and f_{LO1} are mixed together at the U-Mix1 131, thus being up-converted to a frequency f_{TX1} . At this time, the sum of f_{LO1} and f_{MOD} is f_{TX1} . The PA1 141 amplifies the signal having the frequency f_{TX1} from the U-Mix1 131 to the antenna transmission output. The operation of the U-Mix2 132 and the PA2 142 in the signal path TX2 is just as described above, wherein the sum of f_{LO2} and f_{MOD} is f_{TX2} .

Now, the configuration of the LNA block of the dual-band portable telephone will be described in detail with particular focus on the LNA block in FIG. 32.

FIG. 33 illustrates an example of an LNA block of a

conventional dual-band portable telephone. 10 denotes a power supply, 1111 denotes an input terminal of the LNA1 111, 1121 denotes an input terminal of the LNA2 112, 1112 denotes an output terminal of the LNA1 111, 1122 denotes an output terminal of the LNA2 112, 1114 denotes a power supply SW of the LNA1 111, 1124 denotes a power supply SW of the LNA2 112. In FIG. 33, the peripheral matching components, etc., are omitted, and each area surrounded by a broken line denotes an individual device. This also applies to other drawings discussed below.

The power supply SW of the LNA1 1114 is connected between a power supply terminal of the LNA1 111 and the power supply 10, and turns on/off the power supply of the LNA1 111. The power supply SW of the LNA2 1124 is connected between a power supply terminal of the LNA2 112, and turns on/off the power supply of the LNA2 112. The respective ground terminals of the LNA1 111 and the LNA2 112 are both connected to the ground.

In a portable telephone, it is important to reduce the power consumption thereof in order to ensure a long calling time. Therefore, the power supply of a device that is not being operated is typically turned off. Specifically, when the LNA1 111 is operated, the power supply of the LNA2 112 is turned off. Therefore the power supply SW 1114 is turned on and the power supply SW 1124 is turned off. Conversely, when the LNA2 112 is operated, the power supply

of the LNA1 111 is turned off. Therefore, the power supply SW 1124 is turned on and the power supply SW 1114 is turned off. Moreover, during transmission, neither the LNA1 111 nor the LNA2 112 needs to be turned on. Therefore, both of the power supply SWS 1114 and 1124 are turned off.

Typically, a 3- to 4-terminal device such as a transistor or a regulator is used as a power supply SW, and a 3- to 4-terminal device such as an Si bipolar transistor or a GaAs FET is used as an LNA. Therefore, the LNA block as a whole requires a total of 4 devices, i.e., two 3- to 4-terminal devices as power supply SWS and two 3- to 4-terminal devices as LNAs. Moreover, this directly applies to the other three blocks, i.e., PA, D-Mix and U-Mix, as well as the LNA block, and a total of four devices, i.e., two power supply SWS and two amplification devices such as transistors are required for each block.

Thus, when producing a dual-band portable telephone using a conventional device, it requires twice as many components as those for a single-band portable telephone. As a result, the mounting area on the substrate increases, whereby it is difficult to reduce the size of the terminal.

An object of the present invention is to reduce the number of components in a high frequency block of a dual-band portable telephone so as to realize a reduction in the size of the dual-band portable telephone.

DISCLOSURE OF THE INVENTION

In order to achieve the above object, the present invention provides a communication apparatus such as a dual-band portable telephone in which a plurality of LNAs or D-Mixes provided in an LNA block, a D-Mix block, etc., can be selectively switched from one to another without using a power supply SW.

Specifically, a semiconductor apparatus of the invention of claim 1 includes, on a same semiconductor substrate: two or more semiconductor devices to which two or more signals having different frequency ranges are input, respectively; and a constant current source commonly connected to one ends of the semiconductor devices, wherein at least one of the semiconductor devices is provided with a control terminal for turning on/off the semiconductor device.

The invention of claim 2 is the semiconductor apparatus of claim 1, wherein each of the semiconductor devices is a power amplification device.

The invention of claim 3 is the semiconductor apparatus of claim 1, wherein each of the semiconductor devices is a frequency conversion device.

The invention of claim 4 is the semiconductor apparatus of claim 2, wherein the power amplification device is provided by using a field effect transistor.

The invention of claim 5 is the semiconductor apparatus of claim 3, wherein the frequency conversion device

is provided by using a dual-gate type field effect transistor.

The invention of claim 6 is the semiconductor apparatus of claim 1, 2 or 3, including a power supply switch commonly connected to other ends of the semiconductor devices.

5 The invention of claim 7 is the semiconductor apparatus of claim 1, 2 or 3, wherein a constant current value of the constant current source is set to a current value needed for the semiconductor device requiring a lowest distortion among the two or more semiconductor devices.

10 The invention of claim 8 is the semiconductor apparatus of claim 1, 2 or 3, wherein a constant current value of the constant current source is set to a current value needed for the semiconductor device receiving a signal of a highest frequency range among the two or more semiconductor devices.

15 The invention of claim 9 is the semiconductor apparatus of claim 1, 2 or 3, wherein the constant current source is provided by using a field effect transistor and a resistor.

20 The invention of claim 10 is the semiconductor apparatus of claim 1, 2 or 3, wherein the two or more semiconductor devices and the constant current source are sealed in a same package.

25 The invention of claim 11 is the semiconductor apparatus of claim 1, 2 or 3, wherein output terminals of the two or more semiconductor devices are commonly connected and

shared, with an output side return loss being less than or equal to -6 dB over an entire extent of each frequency range.

The invention of claim 12 is the semiconductor apparatus of claim 4 or 5, wherein a grounded capacitor is connected in parallel to the constant current source.

The invention of claim 13 is the semiconductor apparatus of claim 12, wherein an impedance value of the grounded capacitor for a frequency of the signal having a lowest frequency range among the two or more input signals is set to be sufficiently small for an impedance value of the constant current source.

The invention of claim 14 is the semiconductor apparatus of claim 12 or 13, wherein an inductor is connected to a source of the field effect transistor.

The invention of claim 15 is the semiconductor apparatus of claim 14, wherein the inductor is arranged in series with the grounded capacitor.

The invention of claim 16 is the semiconductor apparatus of claim 1, 2 or 3, wherein the constant current source is provided with a control terminal for turning on/off the constant current source.

A communication apparatus of the invention of claim 17 includes a semiconductor apparatus of claim 1 and an antenna, wherein the two or more signals having different frequency ranges that are received by the antenna are input to the respective semiconductor devices, or two or more

signals having different frequency ranges that have been processed by the semiconductor devices are output from the antenna.

According to the invention of claims 1 to 10 and 17,
5 with the above-described configuration, a plurality of semiconductor devices are turned on/off based on the voltage applied to a control terminal provided in at least one of the semiconductor devices, thereby allowing for free selection of any one of the plurality of semiconductor devices. Therefore,
10 only one power supply SW is required while the prior art required the same number of power supply SWs as the number of semiconductor devices, and the plurality of semiconductor devices and the constant current source can be packaged into a single device. Thus, the number of components is reduced,
15 thereby realizing a reduction in the size of the portable terminal.

According to the invention of claim 11, an output terminal is shared by a plurality of semiconductor devices, thereby reducing the number of terminals of a single packaged
20 device.

Furthermore, according to the invention of claims 12 and 13, in a case where each semiconductor device is provided by using a field effect transistor, the source terminal of the field effect transistor is grounded for high frequencies and opened for direct currents by a grounded capacitor,
25 thereby improving the high frequency characteristics.

In addition, according to the invention of claims 14 and 15, a source inductor makes it possible to improve the stability factor of the field effect transistors while ensuring a desirable gain of the field effect transistors, thereby achieving both a low noise figure and a desirable input return loss in the field effect transistors.

Furthermore, according to the invention of claim 16, the power supply SW is eliminated, and the semiconductor block can be provided by using only one device, thereby further reducing the number of components and realizing a reduction in the size of a portable terminal.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagram illustrating a configuration of an LNA block of a dual-band portable telephone according to the first embodiment of the present invention.

FIG. 2(a) is a diagram illustrating a configuration of an LNA block of a dual-band portable telephone according to the second embodiment of the present invention, and FIG. 2(b) is a diagram illustrating the operation of three LNAs based on the combination of potentials of two control terminals provided in the LNA block.

FIG. 3 is a diagram illustrating a configuration of a D-mix block of a dual-band portable telephone according to the third embodiment of the present invention.

FIG. 4 is a diagram illustrating a configuration of

an LNA block of a dual-band portable telephone according to the fourth embodiment of the present invention.

FIG. 5 is a diagram illustrating a variation of the embodiment.

5 FIG. 6(a) is a diagram illustrating a configuration of an LNA block of a dual-band portable telephone according to the fifth embodiment of the present invention, and FIG. 6(b) is a diagram illustrating a specific example of a constant current source.

10 FIG. 7 is a diagram illustrating a first variation of the embodiment.

FIG. 8 is a diagram illustrating a second variation of the embodiment.

15 FIG. 9 is a diagram illustrating a third variation of the embodiment.

FIG. 10 is a diagram illustrating a configuration of an LNA block of a dual-band portable telephone according to the sixth embodiment of the present invention.

20 FIG. 11 is a diagram illustrating a first variation of the embodiment.

FIG. 12 is a diagram illustrating a second variation of the embodiment.

FIG. 13 is a diagram illustrating a third variation of the embodiment.

25 FIG. 14 is a diagram illustrating a configuration of an LNA block of a dual-band portable telephone according to

the seventh embodiment of the present invention.

FIG. 15 is a diagram illustrating a variation of the embodiment.

FIG. 16 is a diagram illustrating a configuration of an LNA block of a dual-band portable telephone according to the eighth embodiment of the present invention.

FIG. 17 is a diagram illustrating a first variation of the embodiment.

FIG. 18 is a diagram illustrating a second variation of the embodiment.

FIG. 19 is a diagram illustrating a third variation of the embodiment.

FIG. 20(a) is a diagram illustrating a fourth variation of the embodiment, and FIG. 20(b) is a diagram illustrating a specific example of a constant current source having a control terminal.

FIG. 21 is a diagram illustrating a fifth variation of the embodiment.

FIG. 22 is a diagram illustrating a sixth variation of the embodiment.

FIG. 23 is a diagram illustrating a seventh variation of the embodiment.

FIG. 24 is a diagram illustrating an eighth variation of the embodiment.

FIG. 25 is a diagram illustrating a ninth variation of the embodiment.

FIG. 26 is a diagram illustrating a tenth variation of the embodiment.

FIG. 27 is a diagram illustrating an eleventh variation of the embodiment.

FIG. 28 is a diagram illustrating a twelfth variation of the embodiment.

FIG. 29 is a diagram illustrating a thirteenth variation of the embodiment.

FIG. 30 shows diagrams each illustrating an adjacent channel leak power which defines the distortion of a digital modulation type power amplifier.

FIG. 31 is a diagram illustrating frequency vs. output side return loss characteristics, illustrating conditions under which an output terminal can be shared by two low noise amplifiers provided in an LNA block.

FIG. 32 is a diagram illustrating an example of a high frequency block of a conventional dual-band portable telephone.

FIG. 33 is a diagram illustrating an example of an LNA block of a conventional dual-band portable telephone.

BEST MODE FOR CARRYING OUT THE INVENTION

Embodiments of the present invention will now be described with reference to the drawings.

Note that the following embodiments only deal with the LNA block and the D-Mix block of a dual-band portable

telephone. While the PA block handles a power greater than that handled by the LNA block, the circuit configuration of the PA block is totally the same as that of the LNA block, and while the frequencies input to the respective terminals of the U-Mix block are different from those for the D-Mix block, the circuit configuration of the U-Mix block is the same as that of the D-Mix block. Therefore, the PA block and the U-Mix block will not be described below.

(FIRST EMBODIMENT)

FIG. 1 illustrates a configuration of an LNA block according to the first embodiment of the present invention, which is provided in a dual-band portable telephone as a communication apparatus. In FIG. 1, 111 denotes a first LNA1 (a semiconductor device and power amplifier device), 112 denotes a second LNA2 (a semiconductor device and power amplifier device), 10 denotes a power supply, 1114 denotes a power supply SW, and 115 denotes a constant current source 1. Moreover, 1111 denotes an input terminal of the first LNA1 111, 1112 denotes an output terminal of the first LNA1 111, 1121 denotes an input terminal of the second LNA2 112, and 1122 denotes an output terminal of the second LNA2 112.

The power supply terminals of the first LNA1 111 and the second LNA2 112 are commonly connected, and the power supply SW 1114 is connected between the common terminal and the power supply 10. Moreover, the ground terminals of the

first LNA1 111 and the second LNA2 112 are commonly connected,
and the constant current source 1 115 is connected between
the common terminal and the ground. Furthermore, the input
terminal 1111 and the output terminal 1112 of the first LNA1
5 and the input terminal 1121 and the output terminal 1122 of
the second LNA2 are each independent as a terminal. High
frequency signals having different frequency ranges from each
other are respectively input to the first LNA1 111 and the
second LNA2 112. The frequency ranges of the high frequency
10 signals may either partially overlap with each other, or be
entirely different with no overlap.

Of the first LNA1 111 and the second LNA2 112, the
first LNA1 111 is provided with a control terminal 1115 for
turning on/off the first LNA1 111. When the potential of the
control terminal 1115 is high, the first LNA1 111 is turned
15 on, and when it is low, the first LNA1 111 is turned off.

As shown in FIG. 1 surrounded by a broken line, the
first LNA1 111, the second LNA2 112 and the constant current
source 1 115 together form a circuit device 117 integrated on
20 the same semiconductor substrate, and the circuit device 117
is sealed in a single package.

Next, the operation of the LNA block illustrated in
FIG. 1 will be described. Now, it is assumed that the
constant current value of the constant current source 1 115
25 is I_1 . With the configuration of FIG. 1, the sum of the
current of the first LNA1 111 and the current of the second

LNA2 112 is always the constant current value I1 because of the constant current source 1 115. Therefore, when a low potential is applied to the control terminal 1115 of the first LNA1 111, the first LNA1 111 is turned off, whereby the current value thereof is "0". At this time, the current value of the second LNA2 112 is the constant current value I1, whereby the second LNA2 112 is turned on. Conversely, when a high potential is applied to the control terminal 1115 of the first LNA1 111, the first LNA1 111 is turned on, whereby the current value of the first LNA1 111 is equal to the constant current value I1, and the second LNA2 112 is turned off with the current value thereof being "0". Thus, the two LNAs 111 and 112 can be switched from one to another based on the voltage applied to the control terminal 1115 of the first LNA1 111 without using the power supply SW 1114. Note that during transmission, the power supply SW 1114 is turned off (closed), thereby turning off both of the LNAs 111 and 112.

The constant current value I1 of the constant current source 1 115 will be described. For an LNA, there exists a minimum current consumption that satisfies the specifications of the high frequency characteristics such as gain and distortion. When an operating current of a value that is greater than the minimum current consumption value is allowed to flow, the high frequency characteristics are basically improved, but there will be a waste of current. Now, assuming that the minimum current consumptions of the first

LNA1 111 and the second LNA2 112 are I_{1min} and I_{2min} , respectively, it is most desirable in the present embodiment that $I_{1min}=I_{2min}$ holds. In such a case, the constant current value I_1 of the constant current source 1 115 is set to $I_{1min}=I_{2min}=I_1$. By this setting, there will be no waste of current consumption.

On the other hand, when the third order intermodulation distortions of the two LNAs, i.e., the LNA1 111 and the LNA2 112, differ from each other, the minimum current consumption values required for the LNA1 111 and the LNA2 112 also differ from each other. In such a case, the minimum current consumption value required for the LNA that has the lower third order intermodulation distortion is greater than the minimum current consumption value of the other LNA of the higher distortion. Therefore, when the minimum current consumption values of the LNAs differ from each other, the constant current value I_1 of the constant current source 1 115 is set to coincide with the minimum current consumption value of the LNA having the lower third order intermodulation distortion. In such a case, when the LNA having the higher third order intermodulation distortion is on, a waste of current in excess of the minimum current consumption value thereof flows through the LNA. Therefore, it is desirable to bring the minimum current consumption values of the LNAs closer to being equal to each other ($I_{1min}=I_{2min}$) by changing the device parameters of the LNA1

111 and the LNA2 112 such as gate length and gate width.

Note that while a case where an LNA is used as a semiconductor device is described in the present embodiment, the present invention can similarly be applied to cases where a PA is used as a semiconductor device. In such a case, since the PA is operated during signal transmission, the power supply SW 1114 is turned off so as to stop the operation of the two PAs during signal reception. Moreover, the setting of the constant current value I_1 of the constant current source 1 115 is as follows. For a digital modulation type PA, the distortion is generally defined by the adjacent channel leak power. The adjacent channel leak power will be described briefly. As illustrated in FIG. 30, when a digital modulation operation is performed with a center frequency f_c , the output wave will have a side lobe as indicated by the symbol "A" in FIG. 30(a), and the side lobe power increases in proportion to the distortion as illustrated in FIG. 30(b). In an adjacent channel whose frequency is displaced by $\pm \Delta f$, the side lobe power is an interfering wave. Therefore, the side lobe power is used as an index of digital modulation type distortion, and the suppression ratio of the $\pm f_w$ to $-f_w$ band width power integrated value centered about $f_c + \Delta f$ with respect to the $\pm f_w$ to $-f_w$ band width power integrated value centered about the center frequency f_c is defined as an adjacent channel leak power P_{adj} . The adjacent channel leak power P_{adj} is normally a negative value, and increases (the

absolute value thereof decreases) as the distortion increases. A digital modulation type PA has a lower distortion and requires a larger current consumption as the adjacent channel leak power P_{adj} decreases (the absolute value thereof increases). Therefore, the constant current value I_1 of the constant current source 1 115 is set to coincide with the current consumption value of one of the two PAs that has the smaller adjacent channel leak power P_{adj} .

An LNA block of the present embodiment is made up of a total of two individual devices, i.e., the single circuit device 117 obtained by integrating together the LNA1 111, the LNA2 112 and the constant current source 1 115 on the same semiconductor substrate, and another device composed of the power supply SW 1114. The conventional LNA block illustrated in FIG. 33 requires a total of four devices, i.e., two devices respectively composed of the two power supply SWs 1114 and 1124, and other two devices respectively composed of the two LNAs 111 and 112. Therefore, as compared with the conventional example, the LNA block of the present embodiment provides a reduction in the number of components, thereby realizing a reduction in the size of a portable terminal.

(SECOND EMBODIMENT)

Next, an LNA block according to the second embodiment of the present invention will be described. While two LNAs are used in the first embodiment, three LNAs are used in the

present embodiment.

FIG. 2(a) illustrates an LNA block according to the present embodiment, wherein a third LNA3 113 is added to the LNA block of FIG. 1. A power supply terminal of the third LNA3 113 is connected to the power supply SW 1114, a ground terminal thereof is connected to the constant current source 1 115, and an input terminal 1131 and an output terminal 1132 thereof are provided independently. Moreover, as the first LNA1 111, the third LNA3 113 is provided with a control terminal 1135 for turning on/off the third LNA3 113.

In the present embodiment, assuming that the current flowing through the first LNA1 111 is I_{11} , the current flowing through the second LNA2 112 is I_{12} , and the current flowing through the third LNA3 113 is I_{13} , the constant current source I_1 is expressed as $I_1 = I_{11} + I_{12} + I_{13}$. As illustrated in FIG. 2(b), the bias setting is such that $I_{11} = I_1$ and $I_{13} = 0$ hold when the control terminal 1115 of the first LNA1 111 is controlled to a high potential and the control terminal 1135 of the third LNA3 113 is controlled to a low potential. In this case, $I_{12} = 0$, whereby only the first LNA1 111 has a current flowing therethrough and is thus turned on. Similarly, the bias setting is such that $I_{11} = 0$ and $I_{13} = I_1$ hold when the control terminal 1115 of the first LNA1 111 is controlled to a low potential and the control terminal 1135 of the third LNA3 113 is controlled to a high potential. In this case, $I_{12} = 0$, whereby only the third LNA3

113 has a current flowing therethrough and is thus turned on. On the other hand, when the respective control terminals 1115 and 1135 of the first LNA1 111 and the third LNA3 113 are controlled to a low potential, $I_{11}=0$ and $I_{13}=0$ hold, whereby only the second LNA2 112 has a current flowing therethrough and is thus turned on.

Therefore, the LNA block of the present embodiment, using three LNAs, also provides a reduction in the number of components, thereby realizing a reduction in the size of a portable terminal, as compared with the conventional example illustrated in FIG. 33.

Note that while it is desirable as in the first embodiment that the minimum current consumption values of the three LNAs are set to be equal to one another and equal to the constant current value I_1 of the constant current source 1 115, when the third order intermodulation distortions thereof are different from one another, the constant current value I_1 is set to coincide with the minimum current consumption value of one of the three LNAs that has the lowest distortion, i.e., the highest minimum current consumption value.

Moreover, while three LNAs are used in the present embodiment, the present invention can of course be applied similarly to cases where four or more LNAs are used.

(THIRD EMBODIMENT)

FIG. 3 illustrates a configuration of a D-Mix block of a dual-band portable telephone according to the third embodiment of the present invention. In the present embodiment, two D-Mixes are used in place of two LNAs as in the first embodiment.

In FIG. 3, 121 denotes a first D-Mix1 (a semiconductor device and frequency conversion device), 122 denotes a second D-Mix2 (a semiconductor device and frequency conversion device), 125 denotes a constant current source 1, 10 denotes a power supply, and 1214 denotes a power supply SW. The first D-Mix1 121 has an input terminal 1211 through which a high frequency signal from an LNA (not shown) is input, an LO input terminal 1213 through which a signal of the frequency fLO1 from a local signal generator VCO (not shown) is input, and an output terminal 1212. Similarly, the second D-Mix2 122 has an input terminal 1221 through which a high frequency signal from another LNA (not shown) is input, an LO input terminal 1223 through which a signal of the frequency fLO2 from another local signal generator VCO (not shown) is input, and an output terminal 1222. The power supply terminals of the two D-Mixes, i.e., the D-Mix1 121 and the D-Mix2 122, are commonly connected, and the power supply SW 1214 is connected between the common terminal and the power supply 10. Moreover, the ground terminals of the D-Mix1 121 and the D-Mix2 122 are commonly connected, and the constant current source 1 125 is connected between the common terminal

and the ground.

Furthermore, of the two D-Mixes, i.e., the D-Mix1 121 and the D-Mix2 122, the first D-Mix1 121 has a control terminal 1215 for turning on/off the first D-Mix1 121.

5 The switching between the two D-Mixes, i.e., the D-Mix1 121 and the D-Mix2 122, is performed by changing the voltage applied to the control terminal 1215 of the first D-Mix1 121 as in the first embodiment. The constant current value of the constant current source 1 125 is set to coincide
10 with the minimum current consumption value of the D-Mix of the lower distortion as in the first embodiment.

The two D-Mixes, i.e., the D-Mix1 121 and the D-Mix2 122, and the constant current source 1 125 are integrated on the same semiconductor substrate to form a single circuit
15 device 123, and the circuit device 123 is sealed in a single package.

The operation of the D-Mix block of the present embodiment is similar to that of the LNA block of the first embodiment, and thus will not be described below.

20 Therefore, the D-Mix block of the present embodiment is also made up of a total of two devices, i.e., the single circuit device 123 and another device composed of the power supply SW 1214. Thus, it is possible to reduce the number of components, thereby realizing a reduction in the size of a
25 portable terminal, as compared with the conventional example illustrated in FIG. 33.

Note that while two D-Mixes are used in the present embodiment, a case where three or more D-Mixes are used is as described above in the second embodiment, and thus will not be described below.

(FOURTH EMBODIMENT)

FIG. 4 illustrates a configuration of an LNA block of a dual-band portable telephone according to the fourth embodiment of the present invention. In the following description, only the differences between the present embodiment and the first embodiment will be described, and those components already described above are provided with the same reference numerals and will not be described below.

Specifically, the output terminal of the second LNA2 112 is connected to the output terminal 1112 of the first LNA1 111, whereby an output terminal is shared by the first LNA1 111 and the second LNA2 112. Therefore, a circuit device 117' provides the effect of reducing the number of terminals by one from that of the circuit device 117 of the first embodiment.

The conditions under which an output terminal can be shared by two LNAs will now be described. In a dual-band portable telephone, the frequency ranges of signals that are respectively input to two LNAs differ from each other. However, if the frequency ranges of the signals are close to each other, an output matching circuit 118 can be shared by

the two LNAs, as illustrated in FIG. 4. Little reflection of power on the output terminal side of the output matching circuit 118 represents a desirably matched state, and in the desirably matched state, the return loss on the output terminal side of the output matching circuit 118 is small, i.e., less than or equal to the setting value, typically less than or equal to -6 dB, as illustrated in FIG. 31. Therefore, the case where the frequency ranges of two signals are close to each other refers to a case where, with the frequency range of the signal that is input to one LNA (e.g., the first LNA1 111) being f11-f12 and with the frequency range of the signal input that is input to the other LNA (the second LNA2 112) being f21-f22, the return loss on the output terminal side of the output matching circuit 118 is less than or equal to the setting value (e.g., -6 dB) in both of the frequency ranges.

FIG. 5 illustrates a variation of the present embodiment. In the fourth embodiment, an output terminal is shared by the two LNAs 111 and 112, which are provided in the LNA block of the dual-band portable telephone. In the variation, an output terminal is shared by the two D-Mixes 121 and 122 provided in the D-Mix block of the dual-band portable telephone of the third embodiment. Specifically, in FIG. 5, the output side of the second D-Mix2 122 is connected to the output terminal 1212 of the first D-Mix1 121, and the output terminal of the second D-Mix 122 is omitted. The

other parts, the conditions under which an output terminal can be shared, etc., are as described above in the fourth embodiment, and thus will not be described below.

5 (FIFTH EMBODIMENT)

FIG. 6(a) illustrates a configuration of an LNA block of a dual-band portable telephone according to the fifth embodiment of the present invention. The present embodiment is a specific implementation of the configuration of FIG. 1, which illustrates the first embodiment. Specifically, in the present embodiment, as an LNA, a field effect transistor (hereinafter referred to as "FET") is used as a source-grounded circuit, and a grounded capacitor is further provided.

10 In FIG. 6(a), 201 denotes an FET1 of the first LNA, 202 denotes an FET2 of the second LNA, and 1114 denotes a power supply SW. Moreover, 2012 denotes a gate bias resistor 1, 20221 denotes a gate bias resistor 2, 20222 denotes a gate bias resistor 3, 2013 denotes a choke inductor 1, 2023 denotes a choke inductor 2, and 211 denotes a grounded capacitor. It is assumed that the FET1 201 and the FET2 202 have an equal threshold value (hereinafter referred to as "Vth"). This also applies to the subsequent embodiments.

20 The drains of the two FETs, i.e., the FET1 201 and the FET2 202, serve as the output terminals 1112 and 1122 and are connected to the choke inductor 1 2013 and the choke

inductor 2 2023, respectively, the other ends of the choke inductors are commonly connected, the power supply SW 1114 is connected to the common terminal, and the other end of the power supply SW 1114 is connected to the power supply 10.

5 Moreover, the sources of the FET1 201 and the FET2 202 are commonly connected, the constant current source 1 115 and the grounded capacitor 211 are connected in parallel to the common terminal, and the other ends thereof are connected to the ground. Moreover, the input terminal 1111 of the first FET1 201 is connected to the control terminal 1115 via the gate bias resistor 1 2012. On the other hand, the input terminal 1121 of the second FET2 202 is connected to the drain of the second FET2 202 and the ground via the gate bias resistor 2 20221 and the gate bias resistor 3 20222, respectively. The power supply SW 1114 is turned off during signal transmission so as to turn off both of the FETs 201 and 202.

10 The grounded capacitor 211 is provided to ground the source terminals of the two FETs 201 and 202 for high frequencies while opening them for direct currents so as to improve the high frequency characteristics. Therefore, the impedance of the grounded capacitor 211 is selected to be a sufficiently small value for the constant current source 1 115 in a frequency to be used. Specifically, with the frequency being f (Hz), the impedance R_c of the grounded capacitor 211 is expressed as $R_c = 1/(2\pi f \times C)$, and if $R \gg R_c$

(typically, $R > 10 \times R_c$) with the impedance of the constant current source 1 115 being R , a substantial portion of the current of the frequency component f flows through the grounded capacitor 211, whereby the voltage between the opposite ends of the grounded capacitor 211 for the frequency component f is substantially "0" (v). In order for the expression $R \gg R_c$ to be satisfied for each of the frequencies of the two input signals, the impedance R_c of the grounded capacitor 211 is set so as to correspond to the lower one of the frequency ranges of the two signals.

Moreover, the two choke inductors, i.e., the choke inductor 1 2013 and the choke inductor 2 2023, are provided to supply DC power supplies to the FET1 201 and the FET2 202, respectively, and to open the impedance of the drain for high frequencies in a frequency to be used. Therefore, the impedance of each of the choke inductor 1 2013 and the choke inductor 2 2023 is selected to be sufficiently large for the load impedance in a frequency to be used.

Furthermore, the gate bias resistor 1 2012 is provided to keep the control terminal 1115 and the input terminal 1111 of the first FET 201 at the same potential for direct currents and to isolate the terminals from each other for high frequencies.

The constant current source 1 115 is provided by using an FET 301 and two resistors 311 and 312 as illustrated in FIG. 6(b), for example. Specifically, one end of the

resistor 311 is connected to the source of the FET 301 and the other end of the resistor 311 is connected to the gate of the FET 301 via the resistor 312.

Note that while the impedance of an evaluation system is typically 50 Ω or 75 Ω , the input/output impedance of the FETs 201 and 202 normally takes a value other than these values. Therefore, in order to efficiently transmit a power to the FETs 201 and 202, there is actually required a matching circuit on the input/output side of each FET. However, the input/output matching circuits are omitted in FIG. 6(a).

The circuit device 117 is obtained by integrating together the FET 201, the FET 202, the gate bias resistor 2 20221, the gate bias resistor 3 20222, the grounded capacitor 211 and the constant current source 1 115 on the same semiconductor substrate.

Next, the operation of the circuit of FIG. 6(a) will be described. Now, it is assumed that the current value of the constant current source 1 115 during signal reception is I_1 . In FIG. 6(a), it is assumed that the gate of the second FET2 202 is set to a voltage V_{g2} by the two gate bias resistors 20221 and 20222. In a case where $V_{g1} < V_{g2}$, wherein V_{g1} is the voltage of the control terminal 1 1115, with the voltage V_{g1} being set to a low potential (e.g., "0" V), the constant current I_1 flows through the second FET2 202 and the current of the first FET1 201 is "0". Therefore, the second

FET2 202 is turned on, and the first FET1 201 is turned off. On the other hand, in a case where the voltage V_{g1} is set to a high potential, whereby $V_{g1} > V_{g2}$, the constant current I_1 flows through the first FET1 201 and the current of the second FET2 202 is "0". Therefore, the first FET1 201 is turned on, and the second FET2 202 is turned off.

Therefore, the present embodiment provides an effect that in a case where an LNA is provided by using an FET and a source-grounded circuit is provided, the source terminal of the FET can be grounded for high frequencies and opened for direct currents by the grounded capacitor 211, thereby improving the high frequency characteristics, in addition to providing the effect that an LNA block can be provided by using a total of two devices, thereby reducing the number of components and realizing a reduction in the size of a portable terminal, as in the first embodiment.

FIG. 7 illustrates a first variation of the present embodiment. The variation shows a configuration similar to that of the D-Mix block of the dual-band portable telephone of the third embodiment (see FIG. 3) except that the two D-mixes are provided by using a first dual-gate FET1 301 and a second dual-gate FET2 302 while the grounded capacitor 211 is arranged in parallel to the constant current source 1 125. Specifically, in FIG. 7, 301 denotes a dual-gate FET1, 302 denotes a dual-gate FET2, 3012 denotes a gate bias resistor 1, 30221 denotes gate bias resistor 2, 30222 denotes gate bias

resistor 3, 3013 denotes a choke inductor 1, and 3023 denotes a choke inductor 2. It is assumed that the dual-gate FET1 301 and the dual-gate FET2 302 have an equal threshold voltage V_{th} . This also applies to the subsequent embodiments.

5 The drains of the dual-gate FET1 301 and the dual-gate FET2 302 are connected to the choke inductor 1 3013 and the choke inductor 2 3023, respectively, the other ends of the choke inductors are commonly connected, the power supply SW 1214 is connected to the common terminal, and the other end of the power supply SW 1214 is connected to the power supply 10. Moreover, the sources of the dual-gate FET1 301 and the dual-gate FET2 302 are commonly connected, the constant current source 1 125 is connected to the common terminal, and the other end of the constant current source 1 125 is connected to the ground. Furthermore, the grounded capacitor 211 is connected in parallel to the constant current source 1 125. In the dual-gate FETs 301 and 302, the input terminal 1211, the input terminal 1221, the output terminal 1212, the output terminal 1222, the LO input terminal 1213 and the LO input terminal 1223 are all independent. The switching between the two D-Mixes is performed by changing the voltage applied to the control terminal 1 1115, which is connected to the input terminal 1211 of the dual-gate FET1 301 via the gate bias resistor 1 3012. Note that the constant current source 1 125 is provided by using the same circuit as that shown in FIG. 6(b).

10013086 100101
TOT280 9800T660

The circuit device 123 is obtained by integrating together the dual-gate FET1 301, the dual-gate FET2 302, the gate bias resistor 2 30221, the gate bias resistor 3 30222, the grounded capacitor 211 and the constant current source 1 125 on the same semiconductor substrate.

Moreover, FIG. 8 and FIG. 9 respectively illustrate a second variation and a third variation of the present embodiment. The second variation shows a configuration similar to that of the LNA block of the dual-band portable telephone of the fourth embodiment (see FIG. 4) except that the two LNAs are provided by using the first dual-gate FET1 201 and the second dual-gate FET2 202 while the grounded capacitor 211 is arranged in parallel to the constant current source 1 125. Furthermore, the third variation shows a configuration similar to that of the D-Mix block of the dual-band portable telephone of the variation of the fourth embodiment (see FIG. 5) except that the two D-Mixes sharing an output terminal are provided by using the first dual-gate FET1 301 and the second dual-gate FET2 302 while the grounded capacitor 211 is arranged in parallel to the constant current source 1 125.

The second and third variations as described above provide the effect that the source terminal of an FET is grounded for high frequencies and opened for direct currents by the grounded capacitor 211, thereby improving the high frequency characteristics, as in the present embodiment.

(SIXTH EMBODIMENT)

FIG. 10 illustrates a configuration of an LNA block according to the sixth embodiment of the present invention.

5 The present embodiment is an improvement to the configuration of FIG. 6(a), which illustrates the fifth embodiment. Specifically, in the LNA block of FIG. 10, which illustrates the present embodiment, an inductor between the source of the FETs and the ground is further added to the configuration of
10 FIG. 6(a).

Specifically, in FIG. 10, an inductor (hereinafter referred to as a "source inductor") 221 is connected in series with the grounded capacitor 211, and the series circuit of the grounded capacitor 211 and the source inductor
15 221 is connected in parallel to the constant current source 115.

In the present embodiment, the source inductor 221 is inserted between the source of the first FET1 201 and the second FET2 202 and the ground, whereby the stability factor
20 of the FETs 201 and 202 is improved, while the impedance "Gain max" at which the input return loss of the FETs 201 and 202 is minimized and the impedance " \tilde{A}_{opt} " at which the noise figure is minimized come close to each other, thereby obtaining a good level of matching and a desirable noise
25 figure. Note, however, the gain of the FETs 201 and 202 decreases as the value of the source inductor 221 increases.

Since the gain of an FET increases as the frequency of an input signal increases, the value of the source inductor 221 is determined in the present embodiment so as to ensure that the gain of the FET whose input signal has the higher frequency is at an appropriate value.

Therefore, in the present embodiment, the provision of the source inductor 221 makes it possible to improve the stability factor of the two FETs 201 and 202 from that in the fifth embodiment while ensuring a desirable gain of the first and second FETs 201 and 202, thereby achieving both a low noise figure and a desirable input return loss in the FETs 201 and 202.

FIG. 11 illustrates a first variation of the present embodiment. The variation is similar to the LNA block of the second variation of the fifth embodiment (see FIG. 8) except that the source inductor 1 221 is connected in series with the grounded capacitor 211 while the series circuit is connected in parallel to the constant current source 1 115. Moreover, FIG. 12 and FIG. 13 illustrate a second variation and a third variation of the present embodiment, respectively. The second variation is similar to the LNA block of the present embodiment illustrated in FIG. 10 except that the position of the source inductor 1 221 is changed to a position between the source of the second FET2 202 and the constant current source 1 115, with only the grounded capacitor 211 being connected in parallel to the constant

current source 1 115. Moreover, the third variation is similar to the LNA block of the first variation of the present embodiment (FIG. 11) except that the position of the source inductor 1 221 is changed as in the second variation.

5 The second and third variations provide effects as those of the present embodiment.

Note that while a case where a source inductor is provided for an LNA block is illustrated in the second and third variations of the present embodiment, it is of course possible to similarly provide a source inductor for a D-mix block, etc.

(SEVENTH EMBODIMENT)

FIG. 14 illustrates a configuration of an LNA block according to the seventh embodiment of the present invention. In the present embodiment, the source inductor 221 of the sixth embodiment is provided separately for each of two FETs.

In the present embodiment, it is assumed that the relationship $f_{RX1} < f_{RX2}$ holds between the frequency f_{RX1} of a signal that is input to the first FET1 201 and the frequency f_{RX2} of a signal that is input to the second FET2 202. In FIG. 14, one end of a source inductor 2 222 is connected to the source of the first FET1 201, and the other end thereof is connected to the source of the second FET2 202. The series circuit of the other source inductor 1 221 and the grounded capacitor 211 and the constant current source 1 115

are connected in parallel to the source of the second FET2 202.

Therefore, in the present embodiment, the sum of the values of the two source inductors 221 and 222 is the source inductor value for the first FET1 201, and the value of the source inductor 1 221 is the source inductor value for the second FET2 202. Thus, the source inductor value is set to be large for the first FET1 201 to which a signal having the low frequency f_{RX1} is input, and the source inductor value is set to be small for the second FET2 202 to which a signal having the high frequency f_{RX2} is input. Since the gain of an FET increases as the frequency of the input signal decreases as already described above in the sixth embodiment, the configuration described above makes it possible to have different source inductor values for the FETs 201 and 202 while having the gains of the two FETs 201 and 202 at substantially the same value, thereby realizing a low noise figure and a desirable input return loss for each of the FETs 201 and 202.

Note that while it is assumed that the respective frequencies of the signals input to the first and second FETs 201 and 202 have the relationship $f_{RX1} < f_{RX2}$ in the present embodiment, it is needless to say that when the relationship is conversely $f_{RX1} > f_{RX2}$, the position of the source inductor 2 221 can be changed to a position between the source of the second FET2 202 and the constant current source 1 115.

FIG. 15 illustrates a variation of the present embodiment. In the variation, the position of the first source inductor 1 221 of the present embodiment is changed to a position between the source of the second FET2 202 and the constant current source 1 115, with only the grounded capacitor 221 being arranged in parallel to the constant current source 1 115. The variation provides effects as those of the present embodiment.

(EIGHTH EMBODIMENT)

FIG. 16 illustrates a configuration of an LNA block according to the eighth embodiment of the present invention. In the present embodiment, the power supply SW 1114 of the first embodiment is not provided, and the function thereof is assigned to a constant current source 2 116.

Specifically, in FIG. 16, no power supply SW is provided. Moreover, the constant current source 2 116 has a control terminal 1161, and the potential of the control terminal 1161 is low during signal transmission and high during signal reception. The output current value of the constant current source 2 116 is "0" when the potential of the control terminal 1161 is low, and is equal to the constant current value I1 when the potential of the control terminal 1161 is high. The constant current source 2 116 having a control terminal is sealed in a single package together with the two LNAs 111 and 112 to form a single

device 117'.

Therefore, as compared with the first embodiment, the present embodiment provides the special effect that the power supply SW 1114 is eliminated, requiring no power supply SW at all, and the LNA block can be provided by using only one device 117'.

FIG. 17 illustrates a first variation of the present embodiment. This variation is similar to the variation of the fourth embodiment except that the power supply SW 1214 is not provided, and the constant current source 1 125 is replaced by a constant current source 2 126 having the control terminal 1261.

FIG. 18 to FIG. 29 respectively illustrate second to thirteen variations of the present embodiment. These variations respectively correspond to the configurations of FIG. 4 to FIG. 15 described above, except that no power supply SW is provided, and the constant current source is provided by using the constant current source 2 116 having the control terminal 1161 or the constant current source 2 126 having a control terminal 1261. Therefore, there is provided the special effect that the LNA block or the D-mix block can be provided by using only one device as in the present embodiment.

An exemplary specific configuration of the constant current source 2 116 having the control terminal 1161 or the constant current source 2 126 having the control terminal

1261 is illustrated in FIG. 20(b). The specific configuration of FIG. 20(b) is similar to that of the constant current source 1 115 illustrated in FIG. 6(b) except that the gate terminal of the FET 301 is replaced by the control terminal 1161. In the constant current source 2 116, the current value needs to be "0" when the potential of the control terminal 1161 is low (0 v) and equal to the constant current value I1 when the potential of the control terminal 1161 is high. Therefore, the FET 301 of the constant current source 2 116 is provided by using an enhancement type FET whose current value is "0" when the gate voltage is "0" v. In such a case, the first FET1 201 and the second FET2 202 may be set to different threshold values V_{th} .

INDUSTRIAL APPLICABILITY

As described above, the semiconductor apparatus and the communication apparatus of the present invention are useful as portable terminals and particularly suitable for reducing the number of components, improving the high frequency characteristics, and providing both a low noise figure and a desirable input return loss in a field effect transistor.

CLAIMS

1. A semiconductor apparatus, comprising, on a same semiconductor substrate:

two or more semiconductor devices to which two or more signals having different frequency ranges are input, respectively; and

a constant current source commonly connected to one ends of the semiconductor devices,

wherein at least one of the semiconductor devices is provided with a control terminal for turning on/off the semiconductor device.

2. The semiconductor apparatus of claim 1, wherein each of the semiconductor devices is a power amplification device.

3. The semiconductor apparatus of claim 1, wherein each of the semiconductor devices is a frequency conversion device.

4. The semiconductor apparatus of claim 2, wherein the power amplification device is provided by using a field effect transistor.

5. The semiconductor apparatus of claim 3, wherein the frequency conversion device is provided by using a dual-gate type field effect transistor.

6. The semiconductor apparatus of claim 1, 2 or 3, comprising

a power supply switch commonly connected to other

ends of the semiconductor devices.

7. The semiconductor apparatus of claim 1, 2 or 3,
wherein a constant current value of the constant
current source is set to a current value needed for the
semiconductor device requiring a lowest distortion among the
two or more semiconductor devices.

8. The semiconductor apparatus of claim 1, 2 or 3,
wherein a constant current value of the constant
current source is set to a current value needed for the
semiconductor device receiving a signal of a highest
frequency range among the two or more semiconductor devices.

9. The semiconductor apparatus of claim 1, 2 or 3,
wherein the constant current source is provided by
using a field effect transistor and a resistor.

10. The semiconductor apparatus of claim 1, 2 or 3,
wherein the two or more semiconductor devices and the
constant current source are sealed in a same package.

11. The semiconductor apparatus of claim 1, 2 or 3,
wherein output terminals of the two or more
semiconductor devices are commonly connected and shared, with
an output side return loss being less than or equal to -6 dB
over an entire extent of each frequency range.

12. The semiconductor apparatus of claim 4 or 5,
wherein a grounded capacitor is connected in parallel
to the constant current source.

13. The semiconductor apparatus of claim 12,

wherein an impedance value of the grounded capacitor for a frequency of the signal having a lowest frequency range among the two or more input signals is set to be sufficiently small for an impedance value of the constant current source.

5 14. The semiconductor apparatus of claim 12 or 13,
 wherein an inductor is connected to a source of the field effect transistor.

 15. The semiconductor apparatus of claim 14,
 wherein the inductor is arranged in series with the grounded capacitor.

 16. The semiconductor apparatus of claim 1, 2 or 3,
 wherein the constant current source is provided with a control terminal for turning on/off the constant current source.

15 17. A communication apparatus, comprising a semiconductor apparatus of claim 1 and an antenna,

 wherein the two or more signals having different frequency ranges that are received by the antenna are input to the respective semiconductor devices, or two or more
20 signals having different frequency ranges that have been processed by the semiconductor devices are output from the antenna.

ABSTRACT

A first low noise amplifier (LNA1 111) is provided with a control terminal (1115) for turning of/off the low noise amplifier (LNA1 111). Power terminals of the low noise amplifier (LNA1 111) and a second low noise amplifier (LNA2 112) are commonly connected, and are connected to a power supply (10) via a power supply switch (1114). Ground terminals of the two amplifiers (LNA1 111) and (LNA2 112) are commonly connected, and a constant current source (1 115) is connected between the common terminal and the ground. The amplifiers (LNA1 111) and (LNA2 112) are turned on/off by switching the voltage applied to the control terminal (1115) of the first low noise amplifier (LNA1 111) between a high potential and a low potential. The power supply switch (1114) is turned off during signal transmission. Therefore, an LNA block can be provided by using only one power supply switch (1114), whereby it is possible to reduce the number of devices from that in the prior art, thereby realizing a reduction in the size thereof.

1/33

Fig. 1

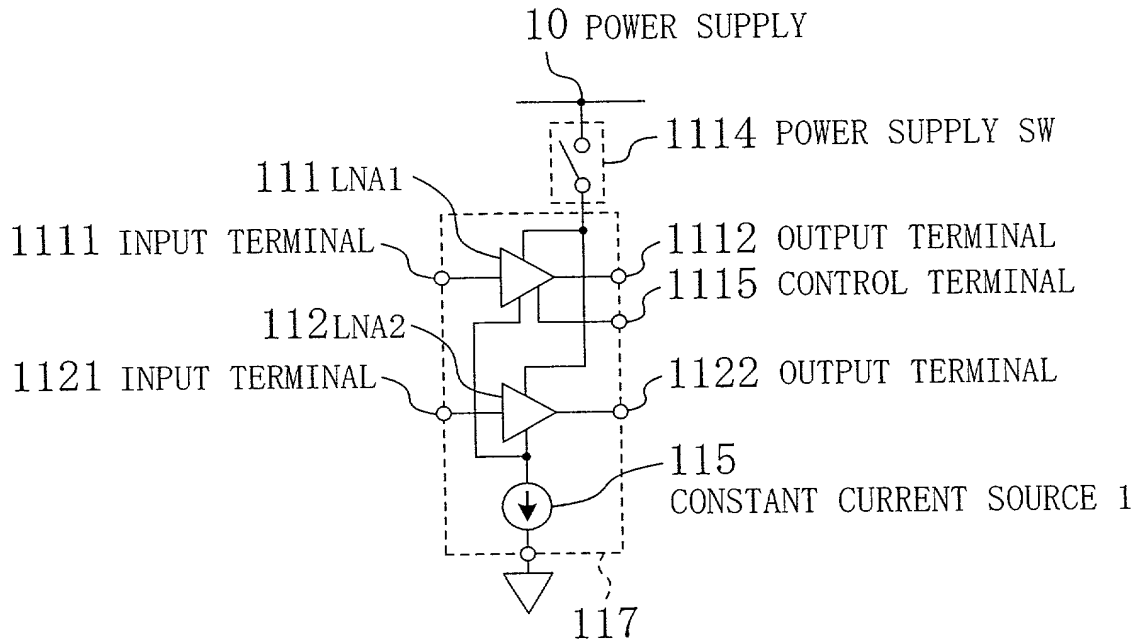


Fig. 2(a)

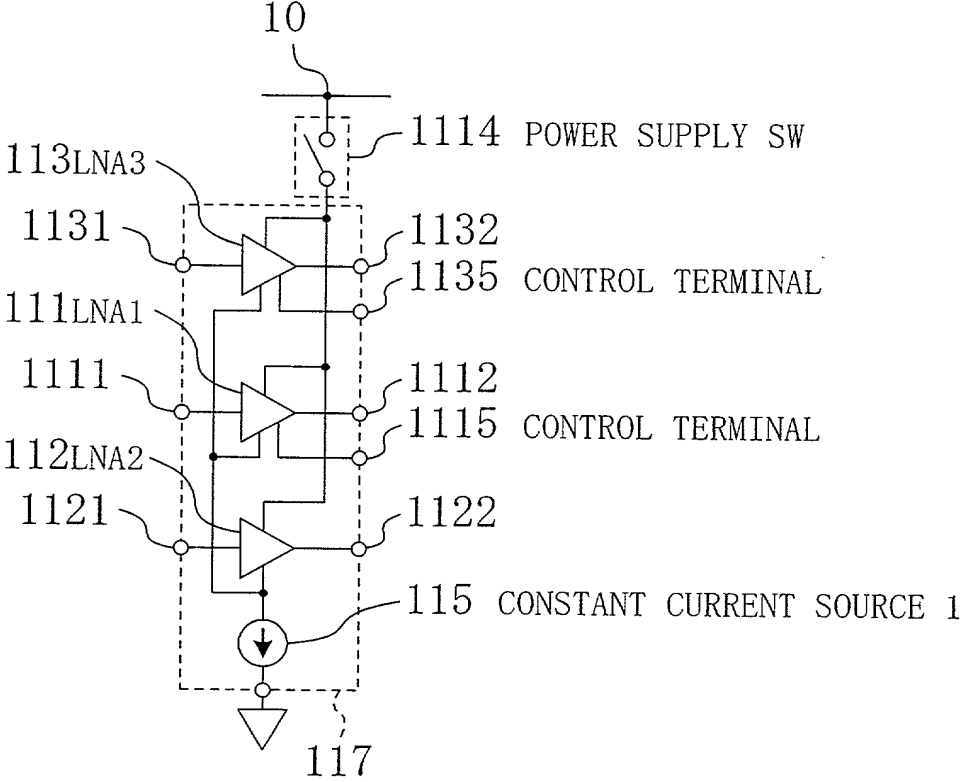


Fig. 2(b)

CONTROL TERMINAL 1115	CONTROL TERMINAL 1135	LNA1	LNA2	LNA3
HIGH	LOW	ON	OFF	OFF
LOW	HIGH	OFF	OFF	ON
LOW	LOW	OFF	ON	OFF

1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050 2051 2052 2053 2054 2055 2056 2057 2058 2059 2060 2061 2062 2063 2064 2065 2066 2067 2068 2069 2070 2071 2072 2073 2074 2075 2076 2077 2078 2079 2080 2081 2082 2083 2084 2085 2086 2087 2088 2089 2090 2091 2092 2093 2094 2095 2096 2097 2098 2099 2100 2101 2102 2103 2104 2105 2106 2107 2108 2109 2110 2111 2112 2113 2114 2115 2116 2117 2118 2119 2120 2121 2122 2123 2124 2125 2126 2127 2128 2129 2130 2131 2132 2133 2134 2135 2136 2137 2138 2139 2140 2141 2142 2143 2144 2145 2146 2147 2148 2149 2150 2151 2152 2153 2154 2155 2156 2157 2158 2159 2160 2161 2162 2163 2164 2165 2166 2167 2168 2169 2170 2171 2172 2173 2174 2175 2176 2177 2178 2179 2180 2181 2182 2183 2184 2185 2186 2187 2188 2189 2190 2191 2192 2193 2194 2195 2196 2197 2198 2199 2200 2201 2202 2203 2204 2205 2206 2207 2208 2209 2210 2211 2212 2213 2214 2215 2216 2217 2218 2219 2220 2221 2222 2223 2224 2225 2226 2227 2228 2229 2230 2231 2232 2233 2234 2235 2236 2237 2238 2239 2240 2241 2242 2243 2244 2245 2246 2247 2248 2249 2250 2251 2252 2253 2254 2255 2256 2257 2258 2259 2260 2261 2262 2263 2264 2265 2266 2267 2268 2269 2270 2271 2272 2273 2274 2275 2276 2277 2278 2279 2280 2281 2282 2283 2284 2285 2286 2287 2288 2289 2290 2291 2292 2293 2294 2295 2296 2297 2298 2299 2300 2301 2302 2303 2304 2305 2306 2307 2308 2309 2310 2311 2312 2313 2314 2315 2316 2317 2318 2319 2320 2321 2322 2323 2324 2325 2326 2327 2328 2329 2330 2331 2332 2333 2334 2335 2336 2337 2338 2339 2340 2341 2342 2343 2344 2345 2346 2347 2348 2349 2350 2351 2352 2353 2354 2355 2356 2357 2358 2359 2360 2361 2362 2363 2364 2365 2366 2367 2368 2369 2370 2371 2372 2373 2374 2375 2376 2377 2378 2379 2380 2381 2382 2383 2384 2385 2386 2387 2388 2389 2390 2391 2392 2393 2394 2395 2396 2397 2398 2399 2400 2401 2402 2403 2404 2405 2406 2407 2408 2409 2410 2411 2412 2413 2414 2415 2416 2417 2418 2419 2420 2421 2422 2423 2424 2425 2426 2427 2428 2429 2430 2431 2432 2433 2434 2435 2436 2437 2438 2439 2440 2441 2442 2443 2444 2445 2446 2447 2448 2449 2450 2451 2452 2453 2454 2455 2456 2457 2458 2459 2460 2461 2462 2463 2464 2465 2466 2467 2468 2469 2470 2471 2472 2473 2474 2475 2476 2477 2478 2479 2480 2481 2482 2483 2484 2485 2486 2487 2488 2489 2490 2491 2492 2493 2494 2495 2496 2497 2498 2499 2500 2501 2502 2503 2504 2505 2506 2507 2508 2509 2510 2511 2512 2513 2514 2515 2516 2517 2518 2519 2520 2521 2522 2523 2524 2525 2526 2527 2528 2529 2530 2531 2532 2533 2534 2535 2536 2537 2538 2539 2540 2541 2542 2543 2544 2545 2546 2547 2548 2549 2550 2551 2552 2553 2554 2555 2556 2557 2558 2559 2560 2561 2562 2563 2564 2565 2566 2567 2568 2569 2570 2571 2572 2573 2574 2575 2576 2577 2578 2579 2580 2581 2582 2583 2584 2585 2586 2587 2588 2589 2590 2591 2592 2593 2594 2595 2596 2597 2598 2599 2600 2601 2602 2603 2604 2605 2606 2607 2608 2609 2610 2611 2612 2613 2614 2615 2616 2617 2618 2619 2620 2621 2622 2623 2624 2625 2626 2627 2628 2629 2630 2631 2632 2633 2634 2635 2636 2637 2638 2639 2640 2641 2642 2643 2644 2645 2646 2647 2648 2649 2650 2651 2652 2653 2654 2655 2656 2657 2658 2659 2660 2661 2662 2663 2664 2665 2666 2667 2668 2669 2670 2671 2672 2673 2674 2675 2676 2677 2678 2679 2680 2681 2682 2683 2684 2685 2686 2687 2688 2689 2690 2691 2692 2693 2694 2695 2696 2697 2698 2699 2700 2701 2702 2703 2704 2705 2706 2707 2708 2709 2710 2711 2712 2713 2714 2715 2716 2717 2718 2719 2720 2721 2722 2723 2724 2725 2726 2727 2728 2729 2730 2731 2732 2733 2734 2735 2736 2737 2738 2739 2740 2741 2742 2743 2744 2745 2746 2747 2748 2749 2750 2751 2752 2753 2754 2755 2756 2757 2758 2759 2760 2761 2762 2763 2764 2765 2766 2767 2768 2769 2770 2771 2772 2773 2774 2775 2776 2777 2778 2779 2780 2781 2782 2783 2784 2785 2786 2787 2788 2789 2790 2791 2792 2793 2794 2795 2796 2

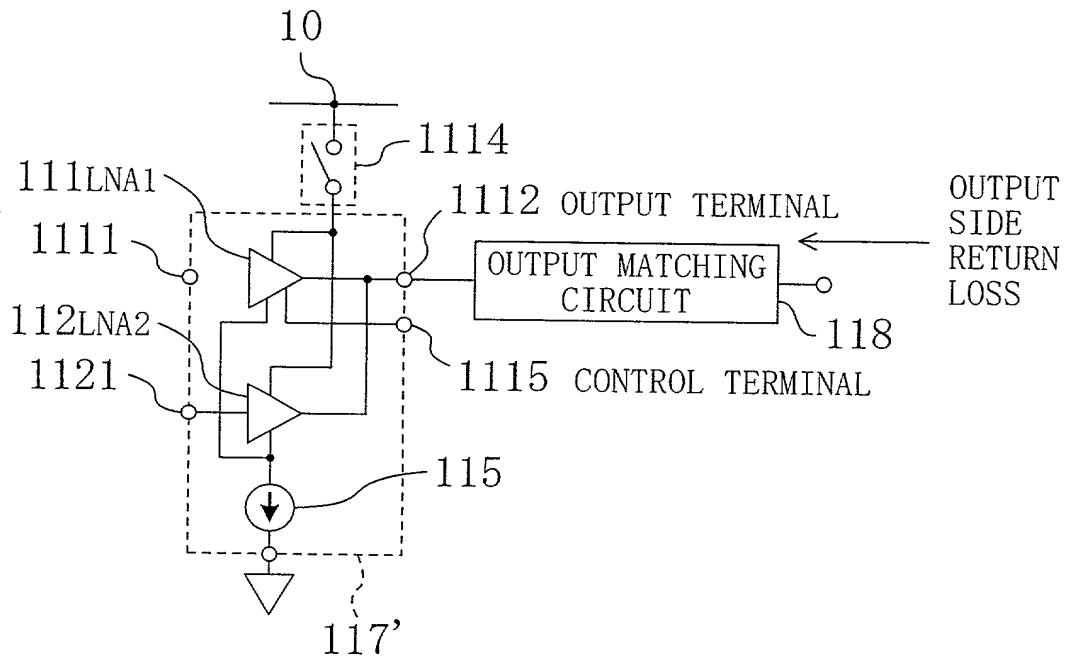
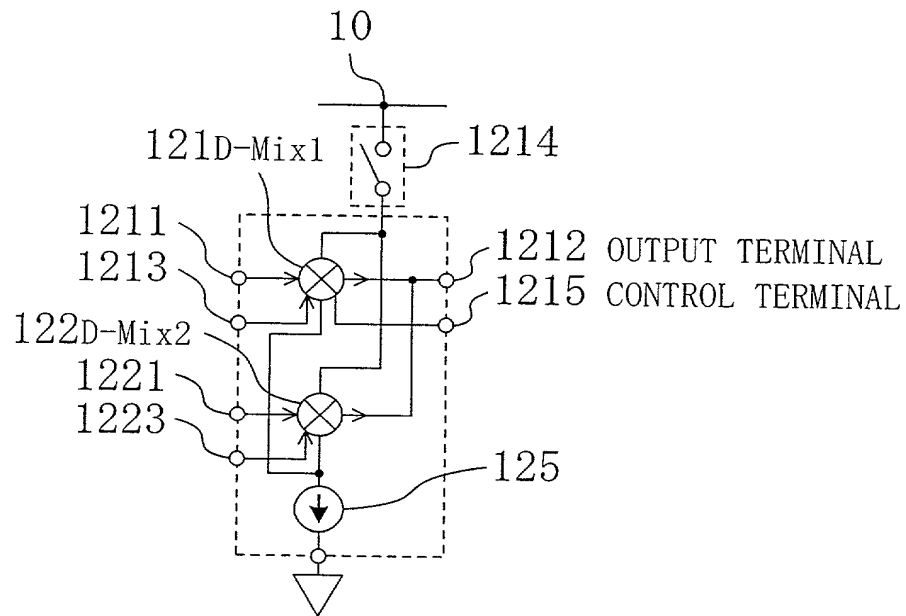


Fig. 5



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Fig. 6(a)

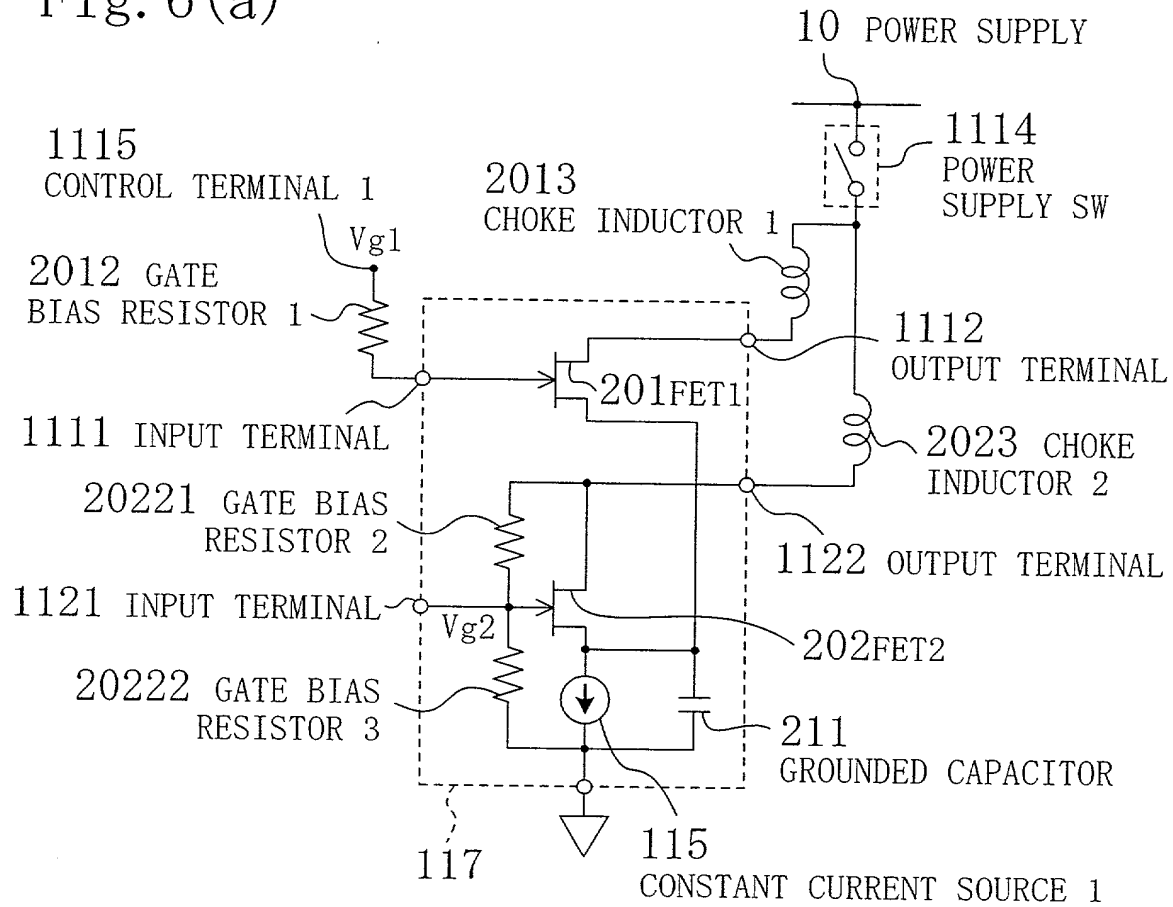
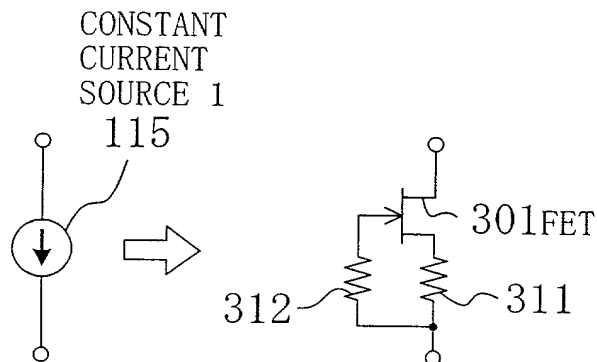


Fig. 6(b)



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Fig. 7

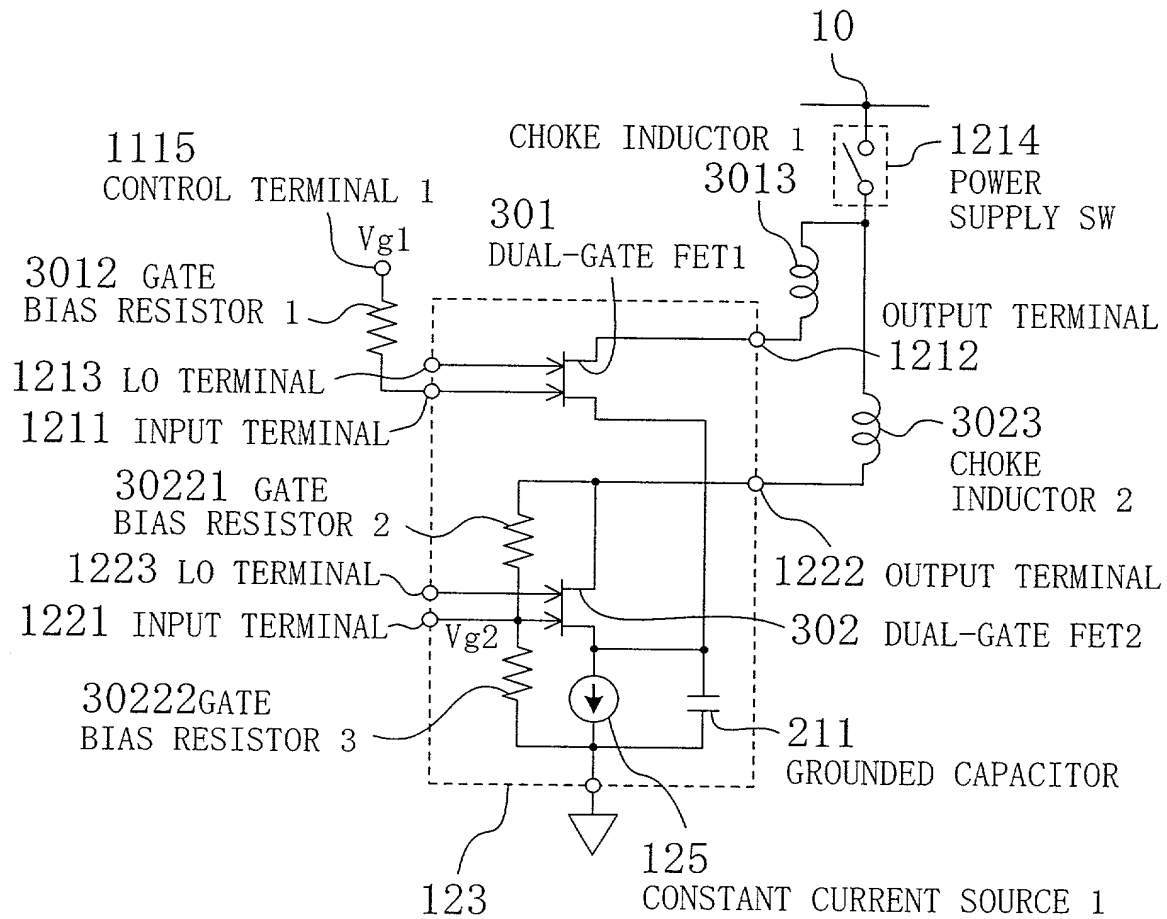
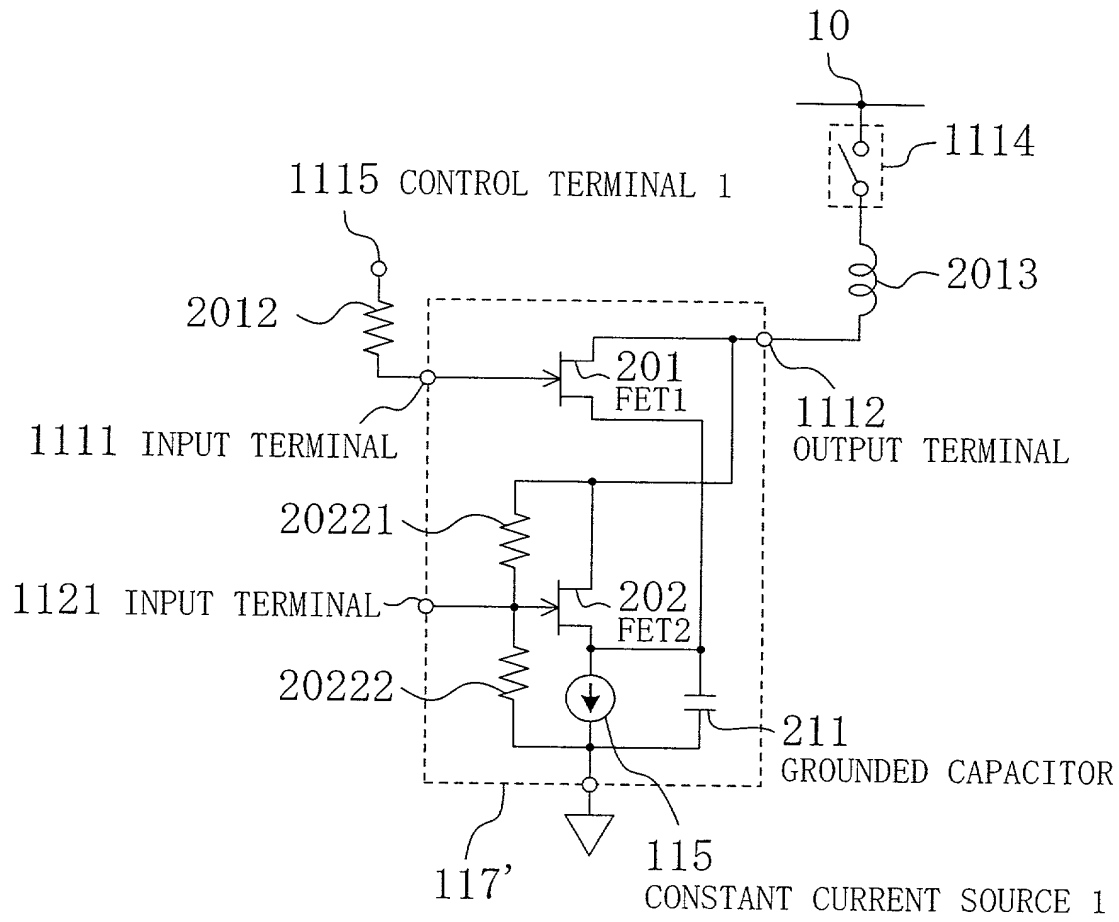
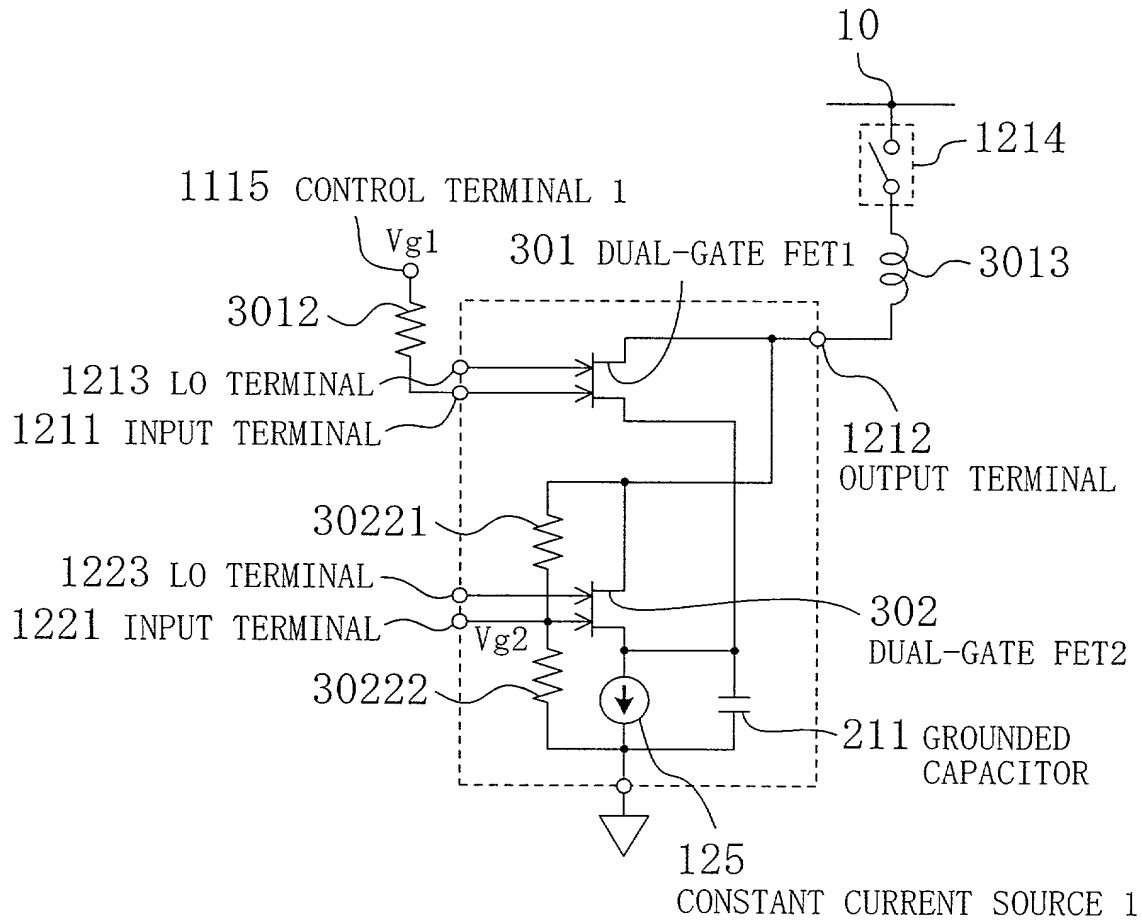


Fig. 8



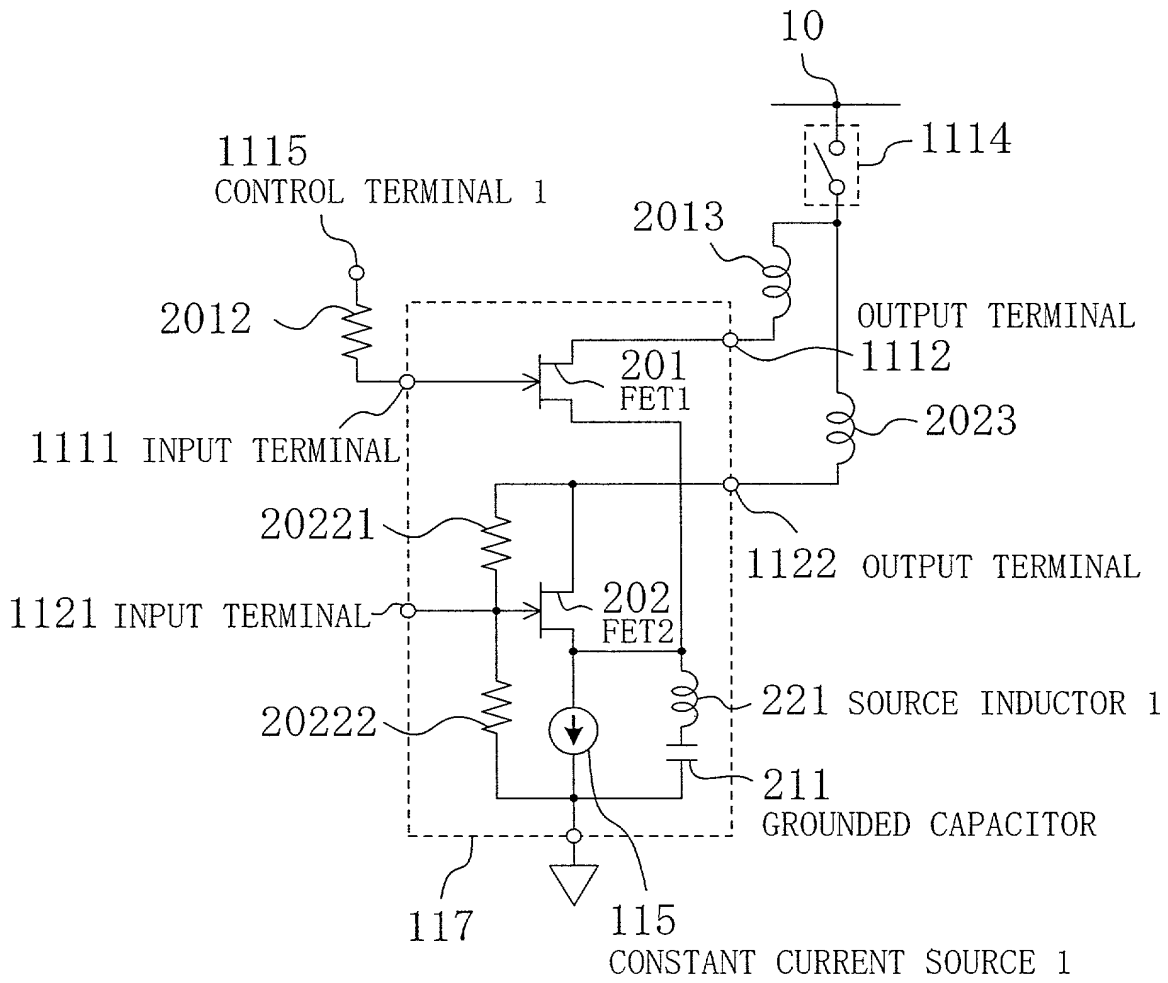
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Fig. 9



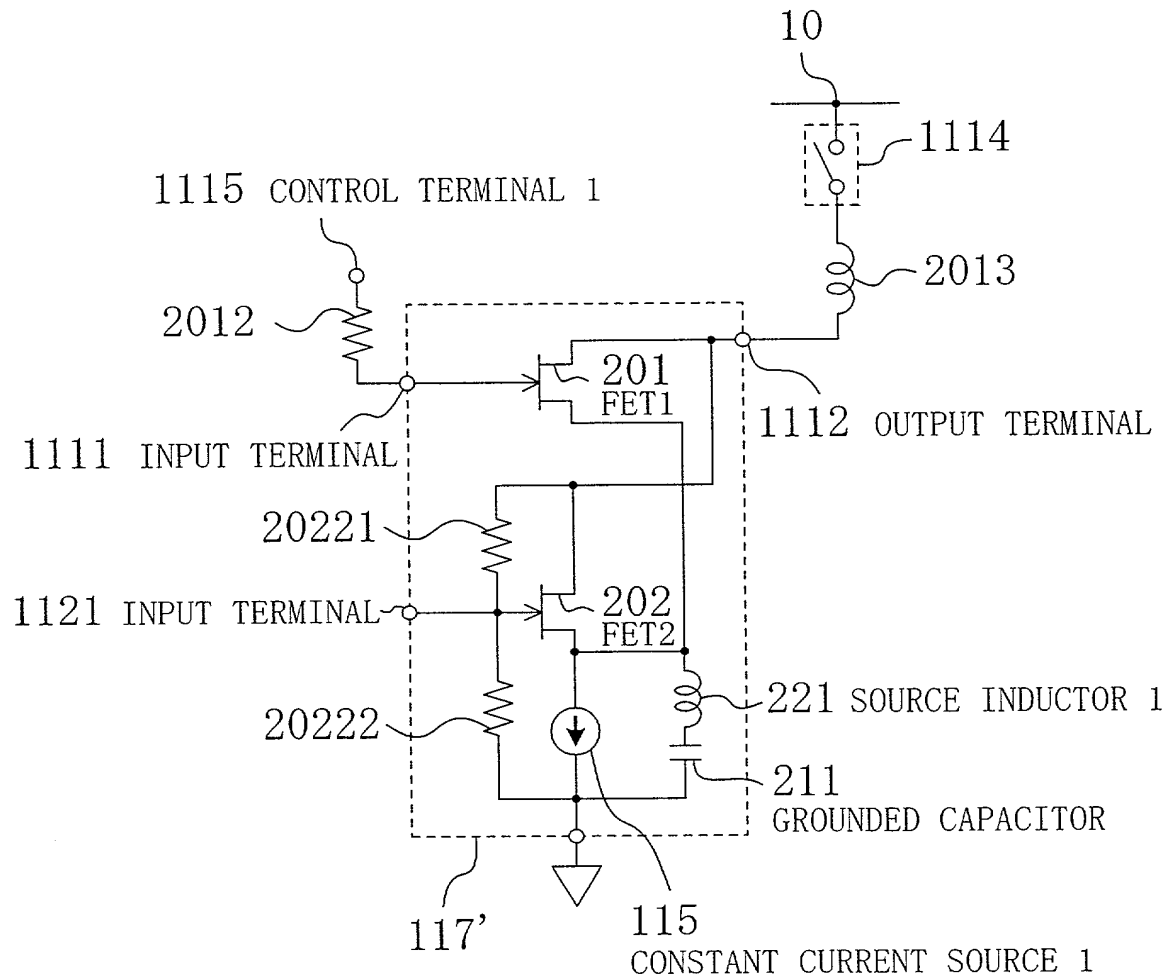
09/913886-0001

Fig. 10



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Fig. 11



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Fig. 12

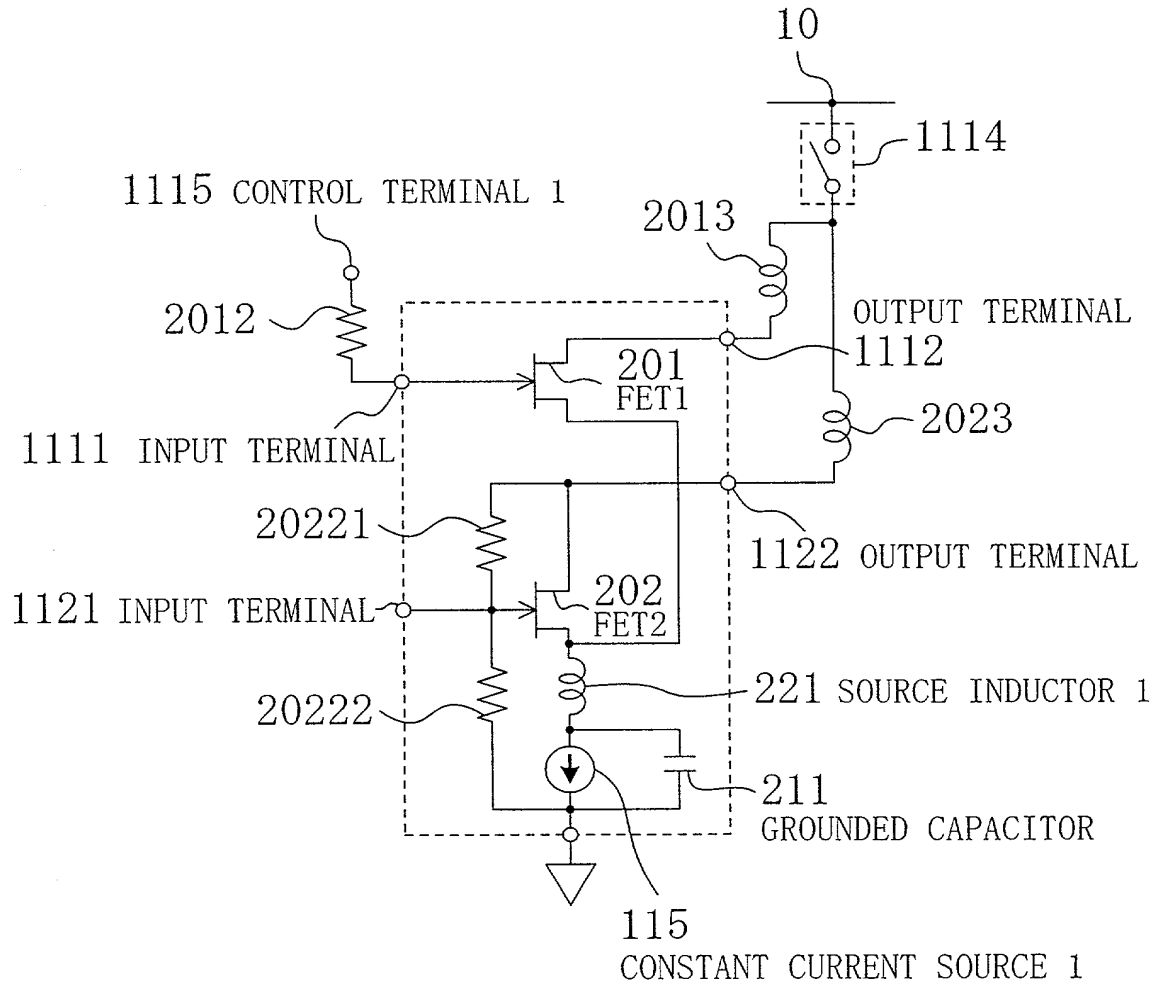


Fig. 13

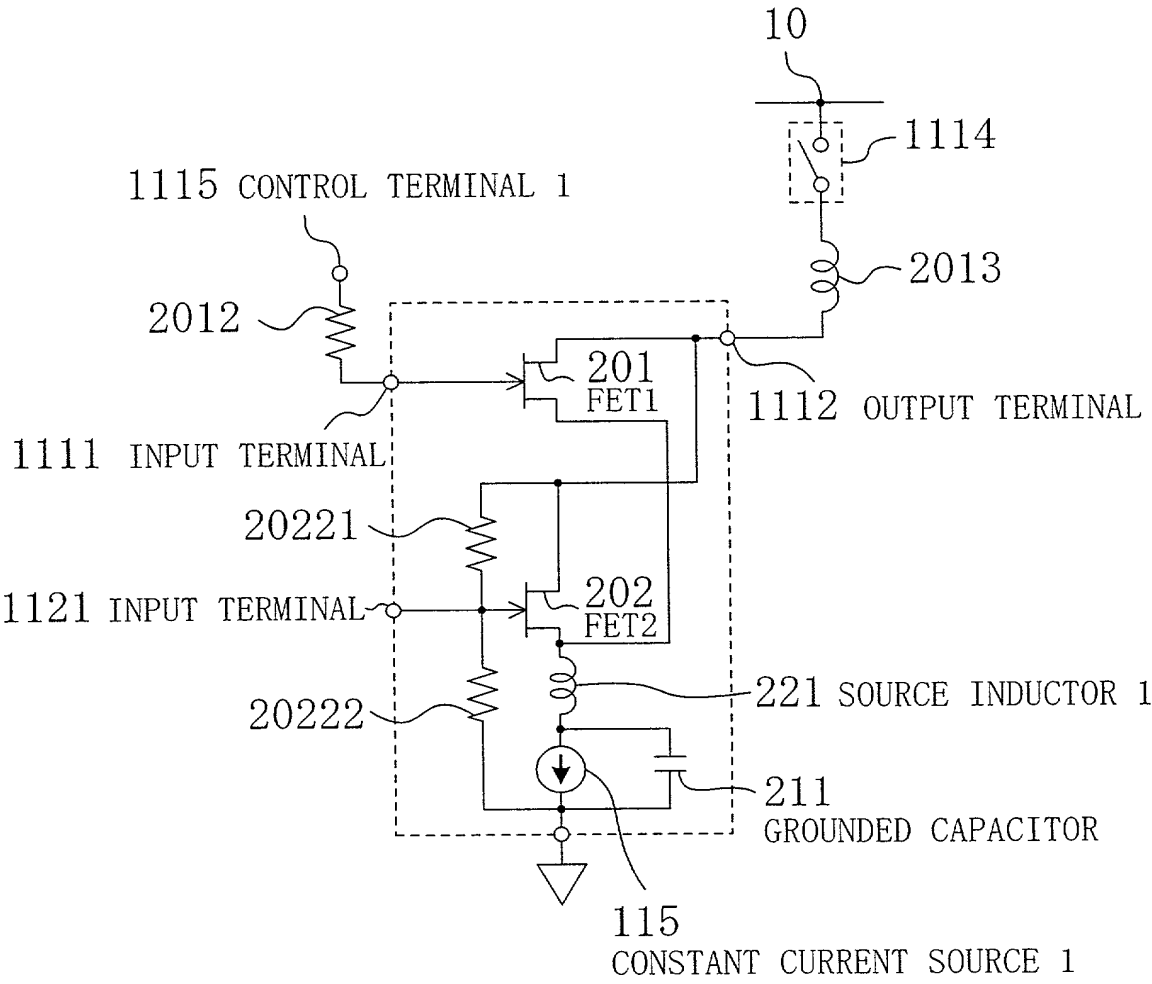
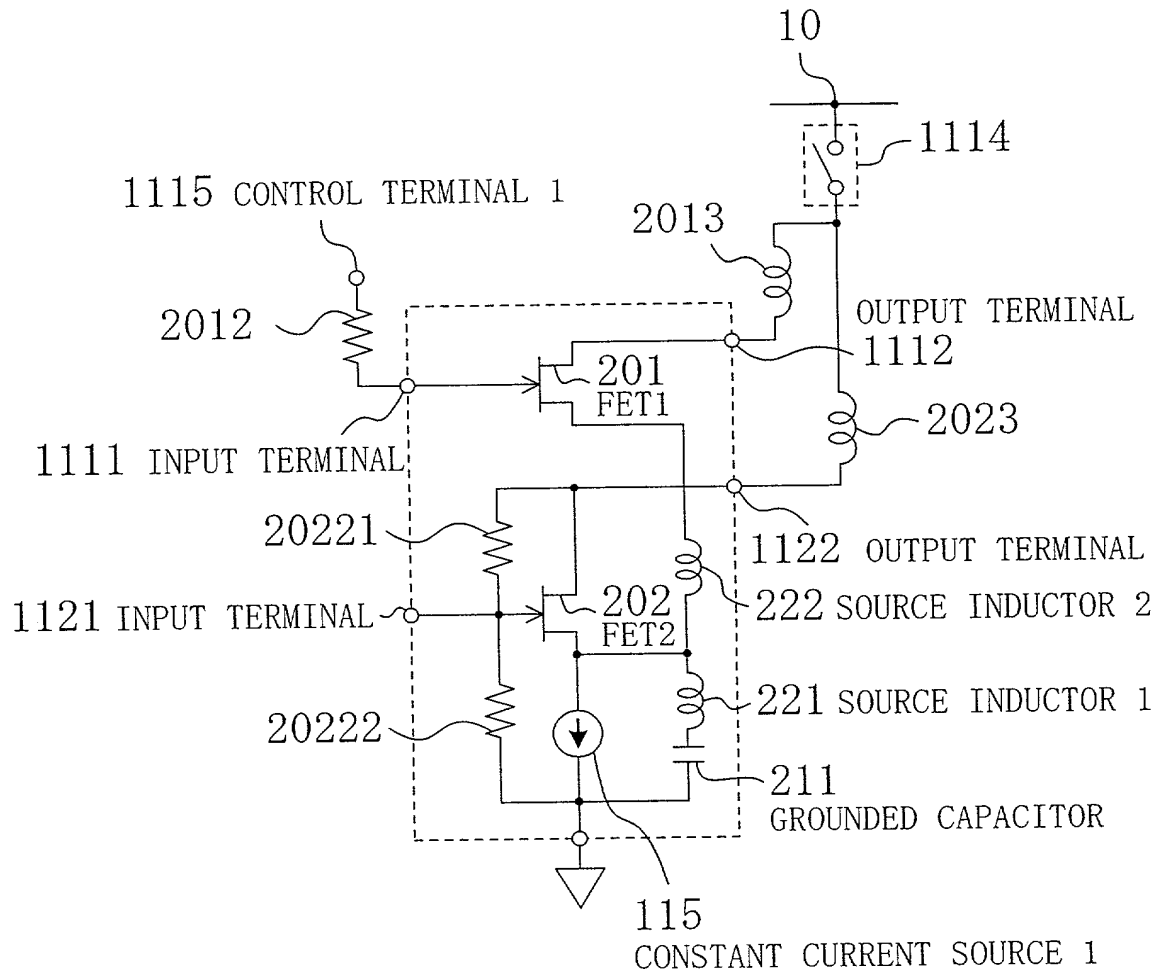


Fig. 14



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Fig. 15

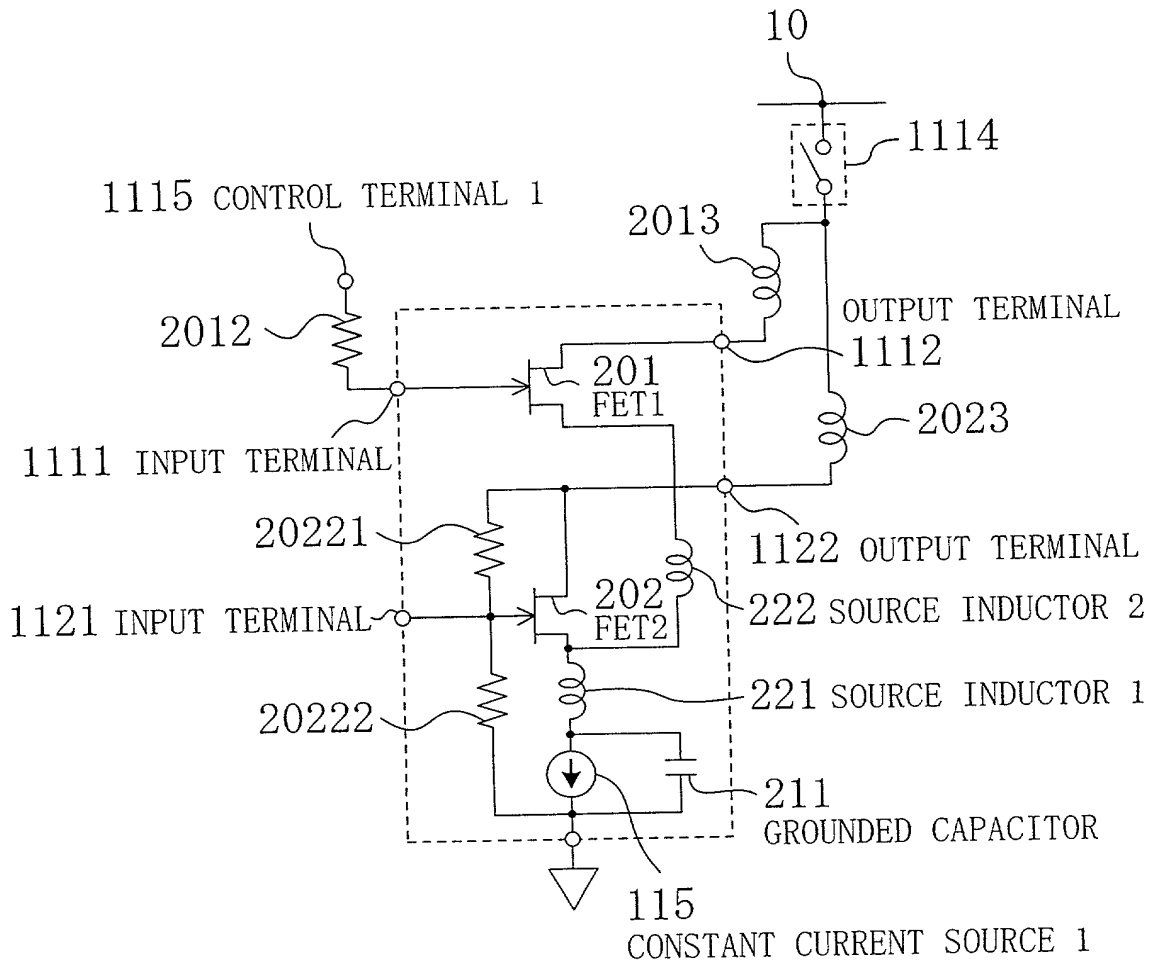
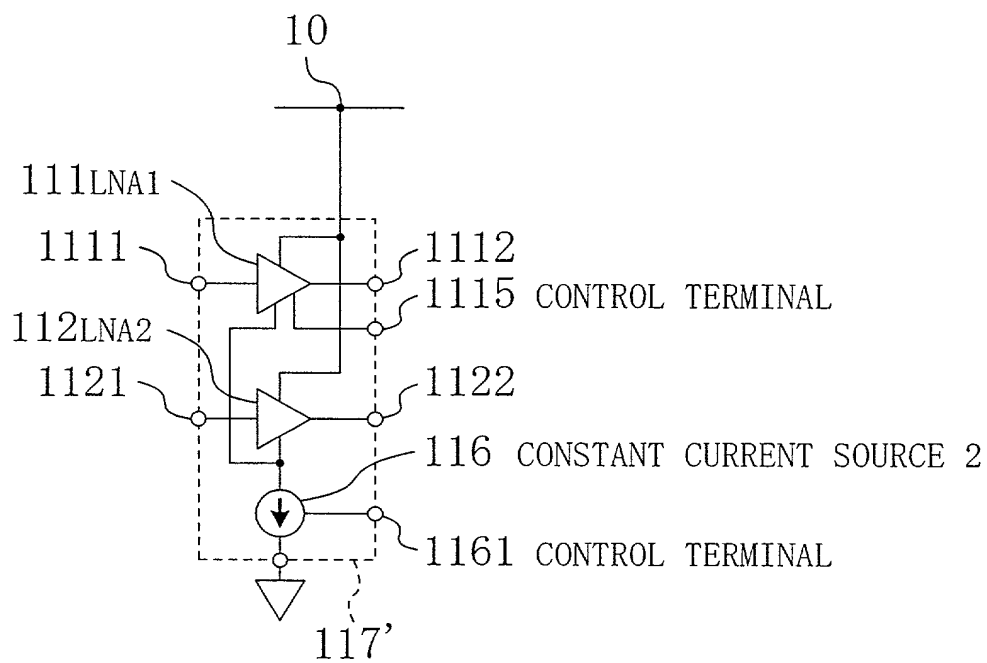
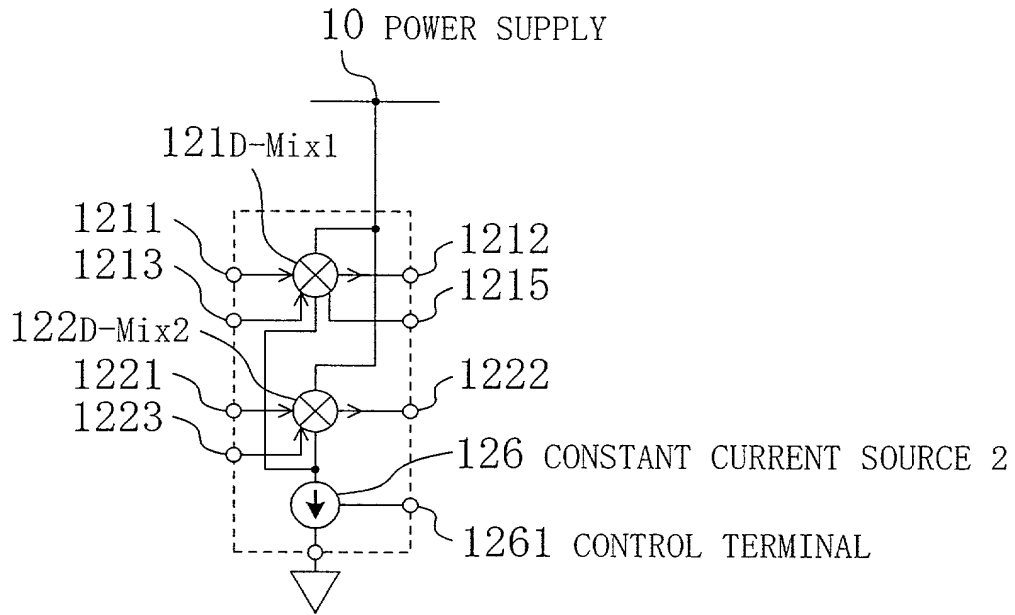


Fig. 16



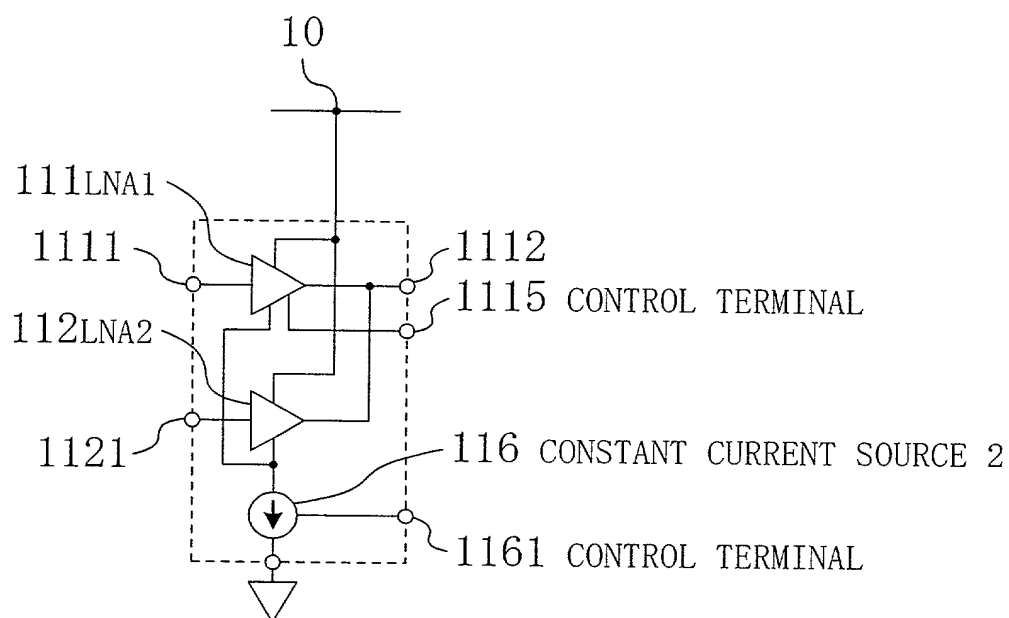
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Fig. 17



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Fig. 18



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Fig. 19

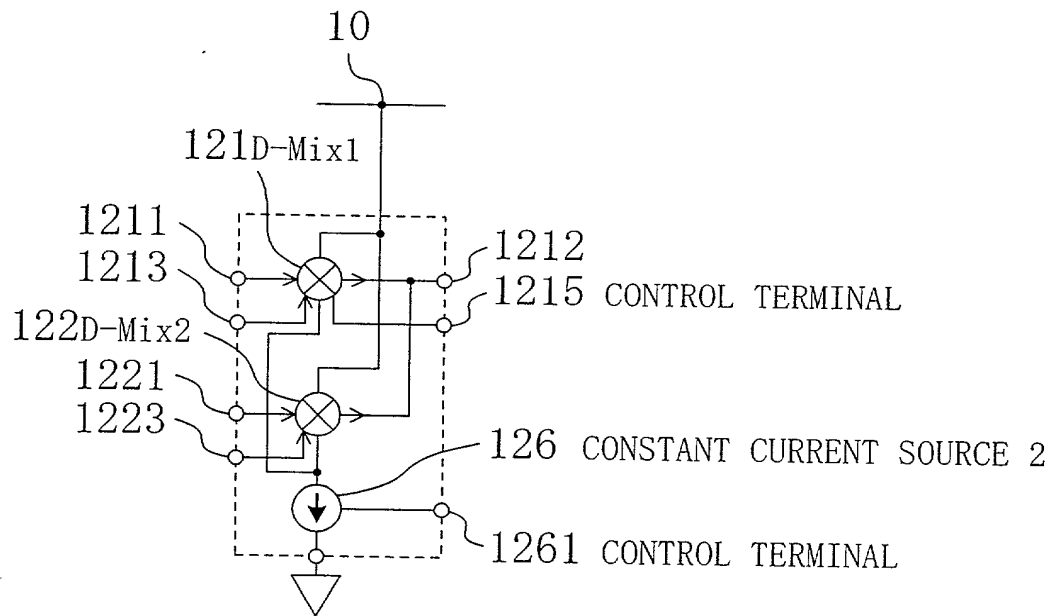


Fig. 20 (a)

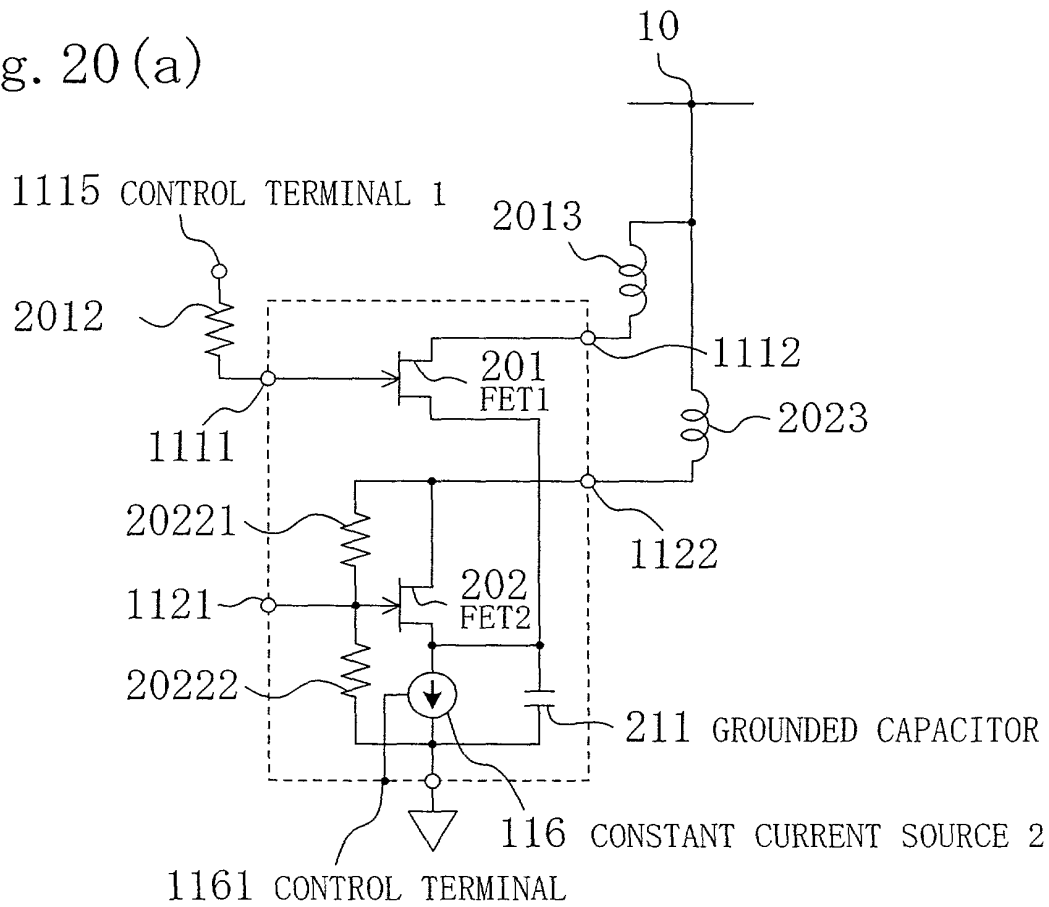


Fig. 20 (b)

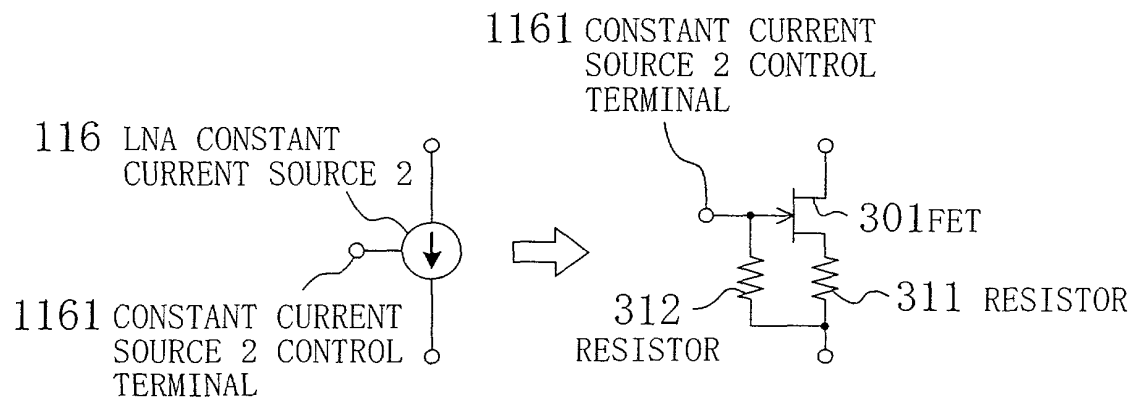


Fig. 21

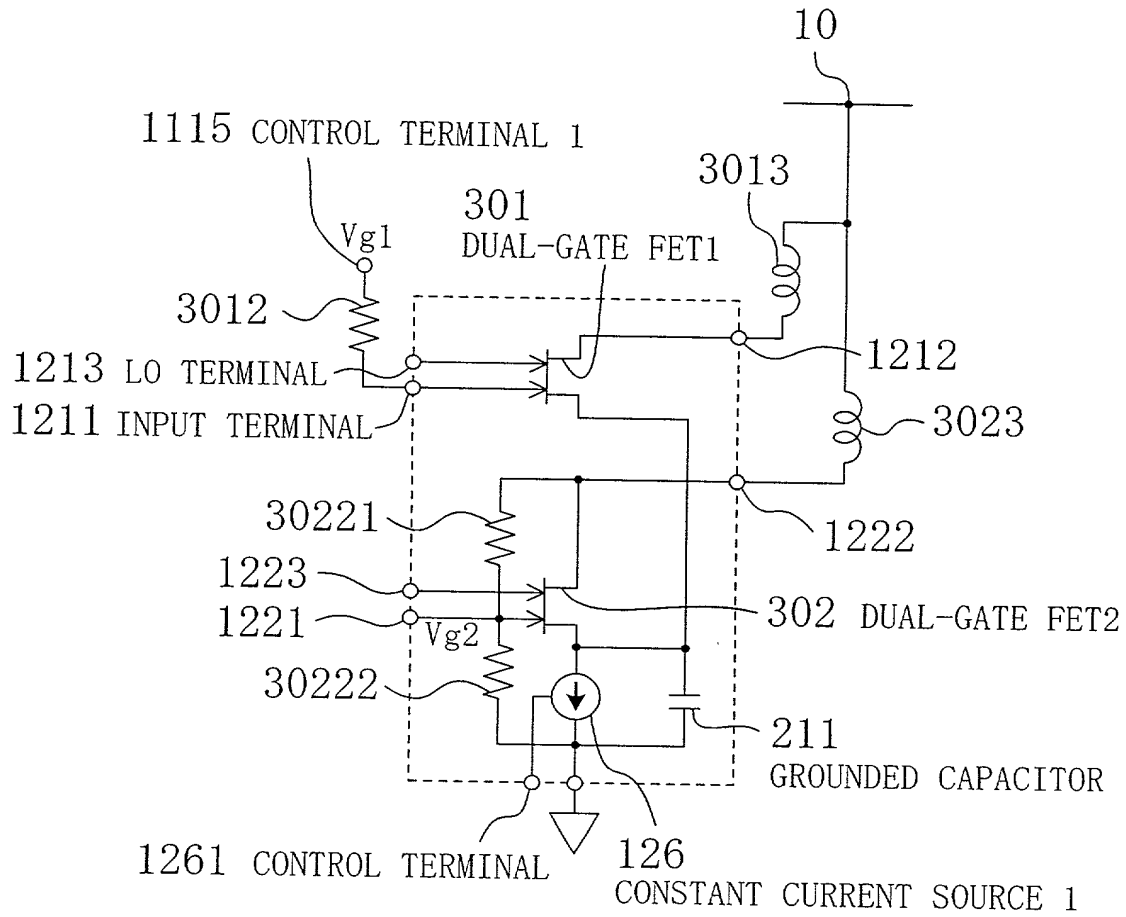


Fig. 22

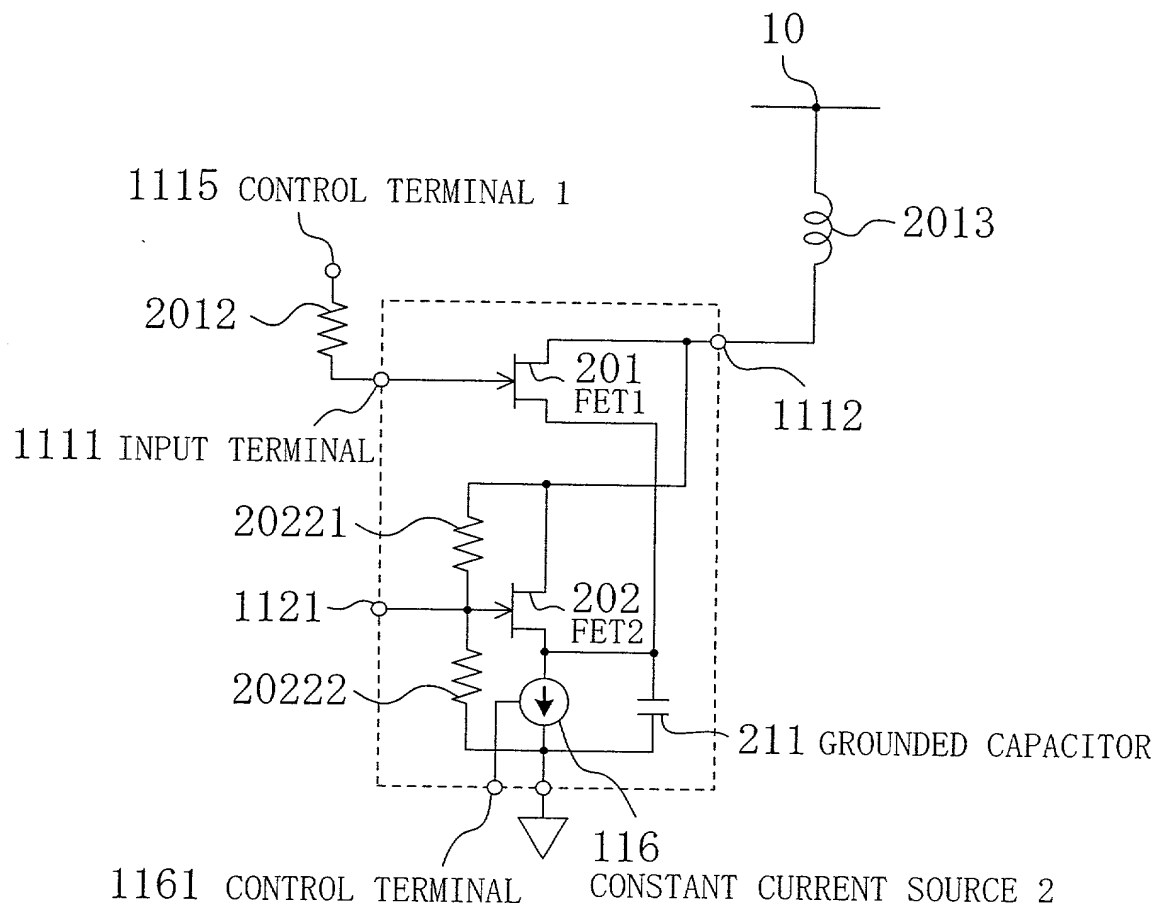


Fig. 23

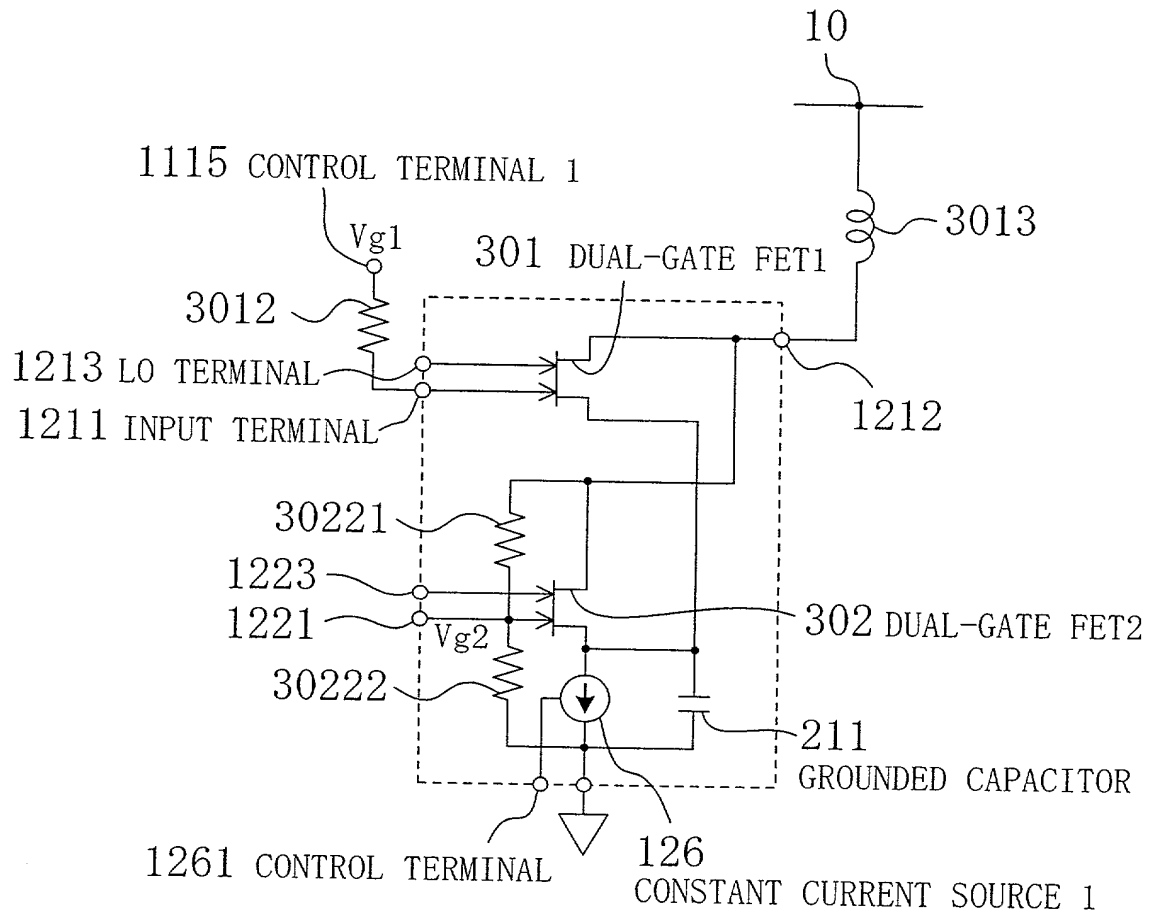


Fig. 25

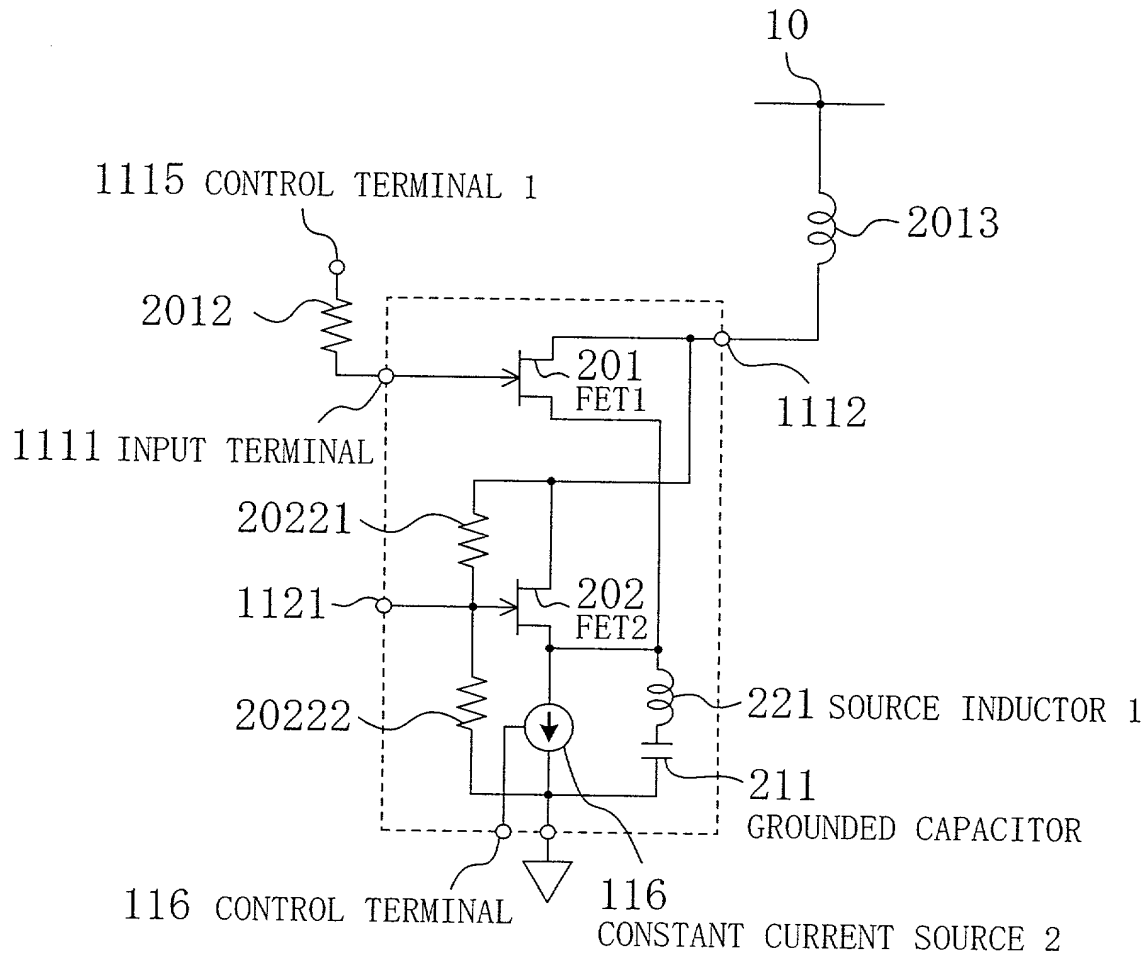


Fig. 26

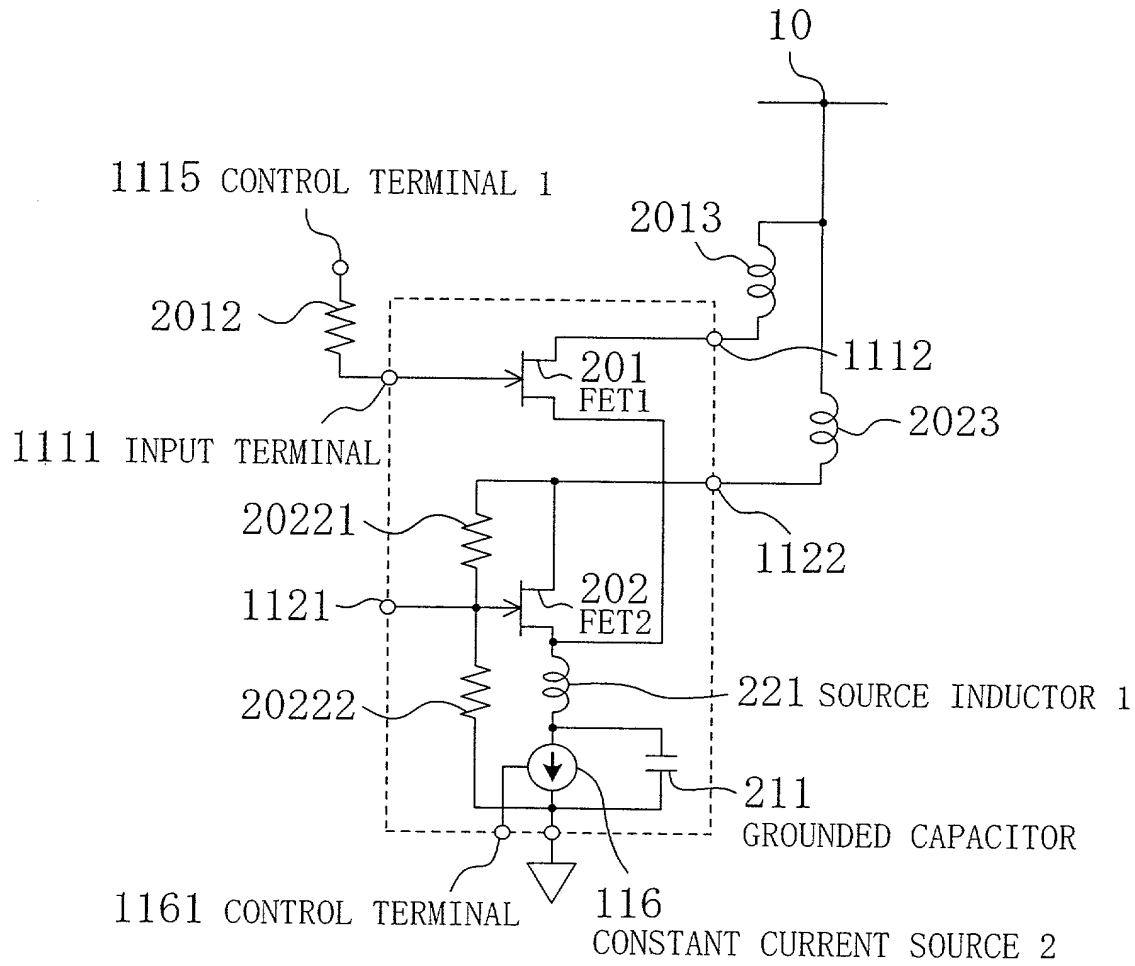


Fig. 27

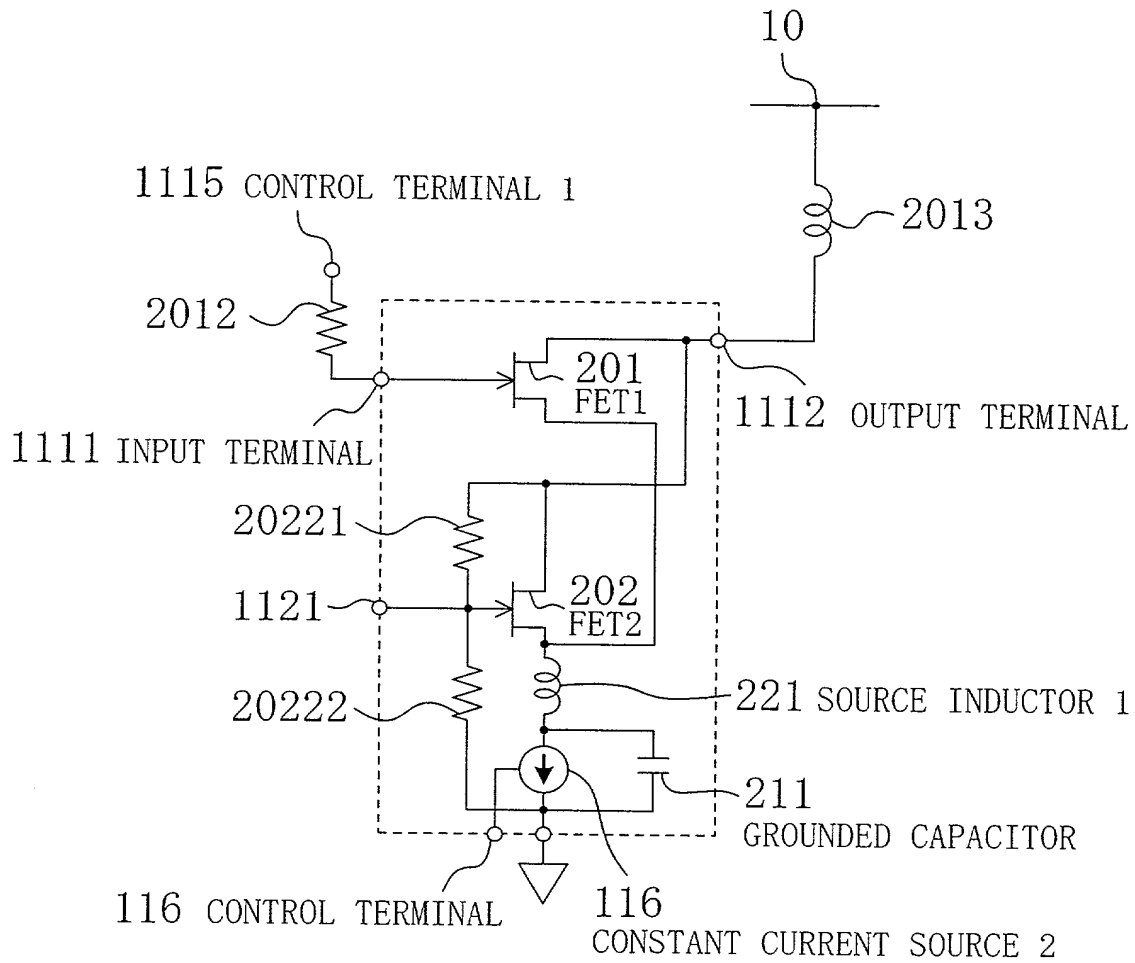


Fig. 28

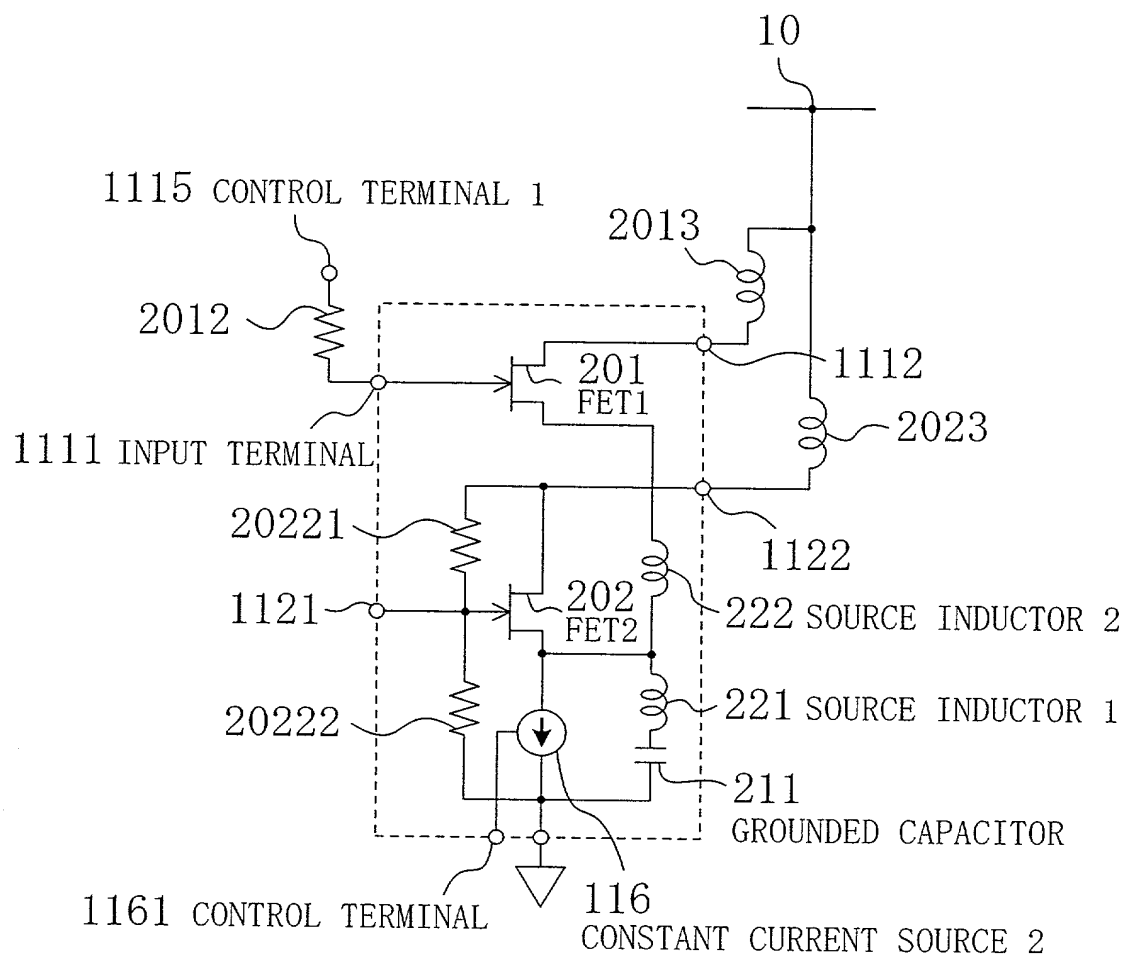


Fig. 29

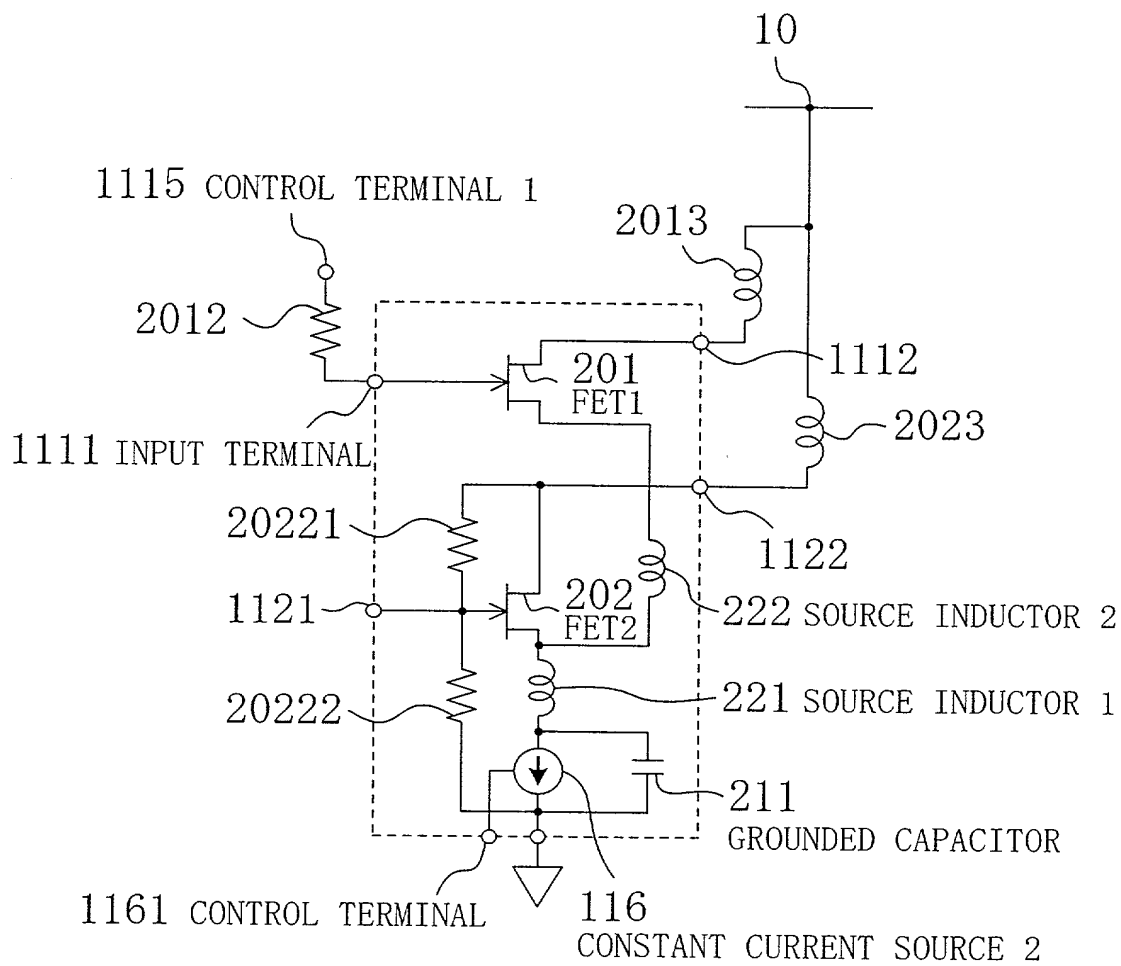


Fig. 30(a)

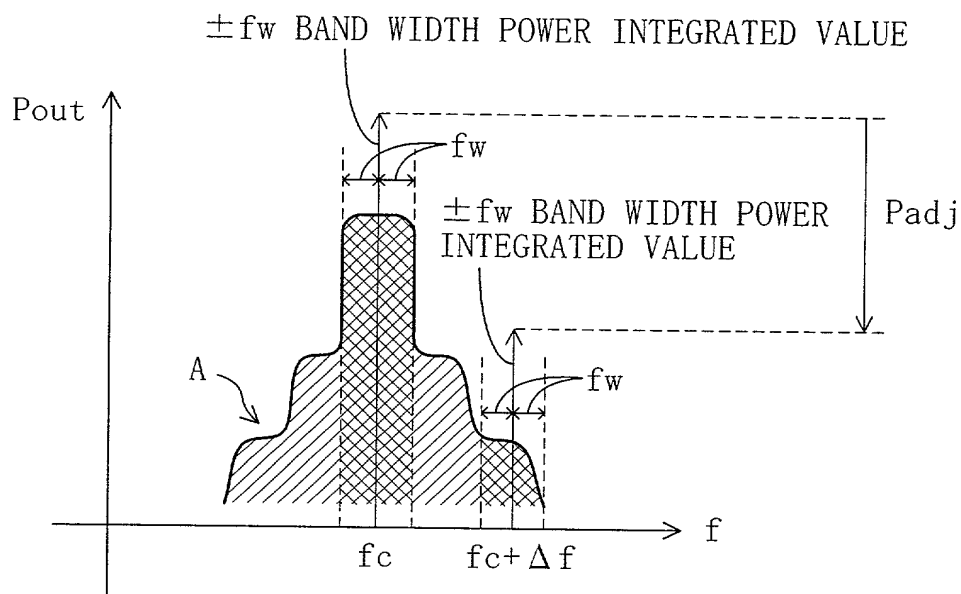
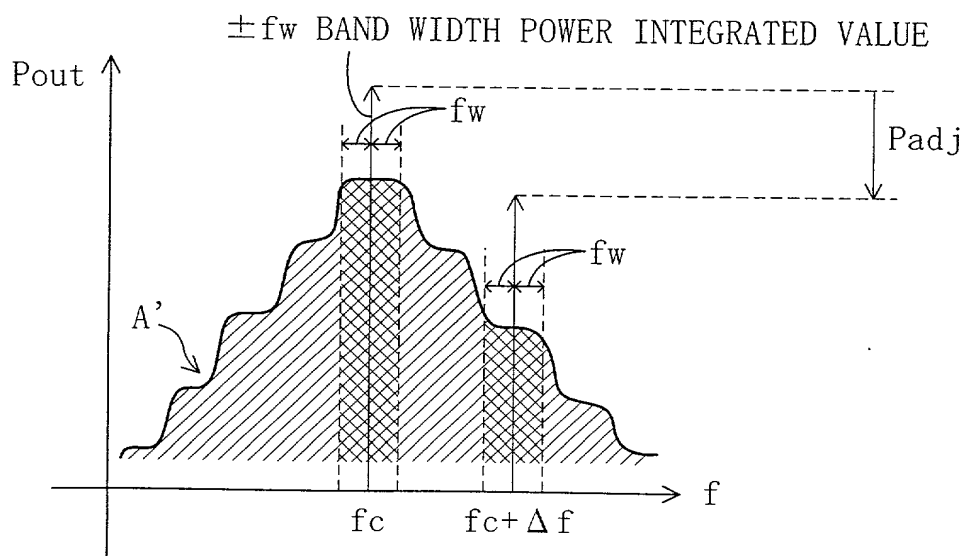


Fig. 30(b)



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Fig. 31

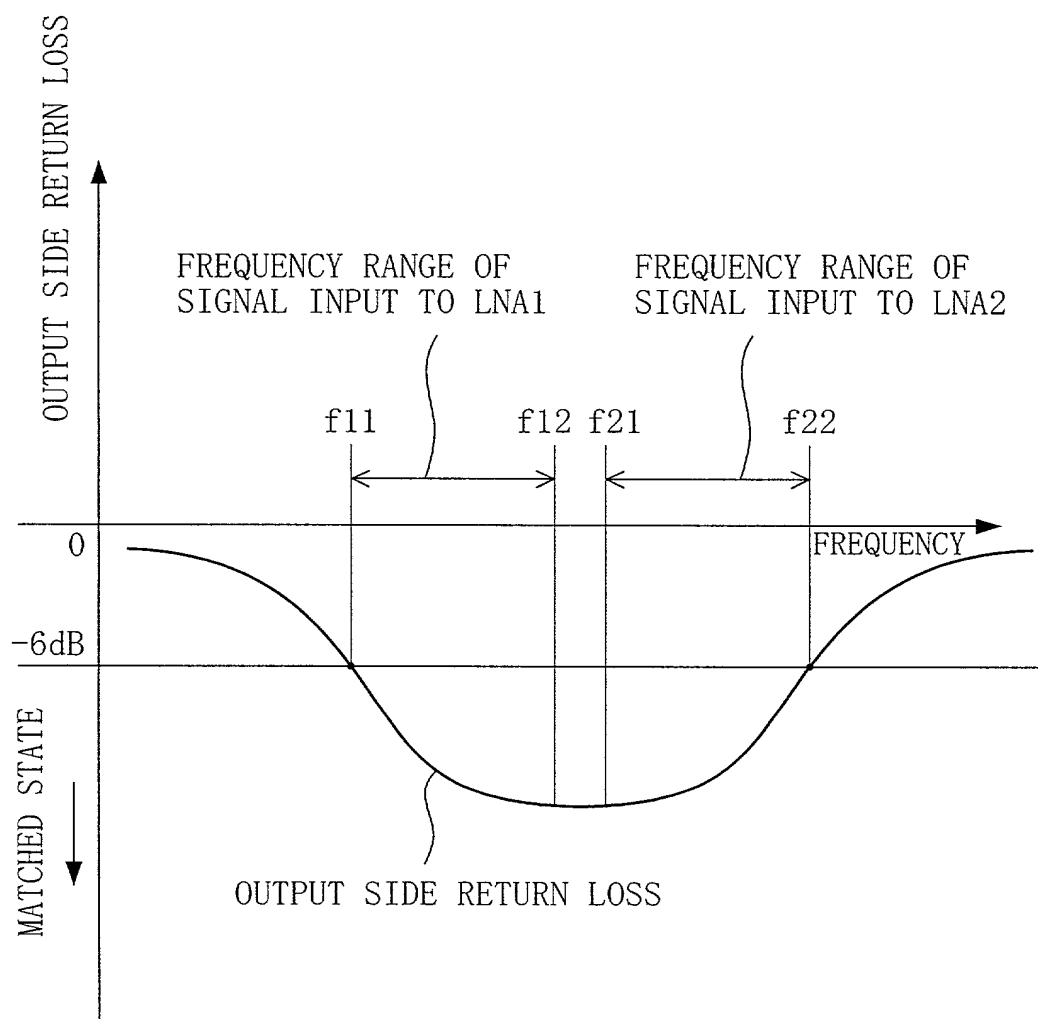
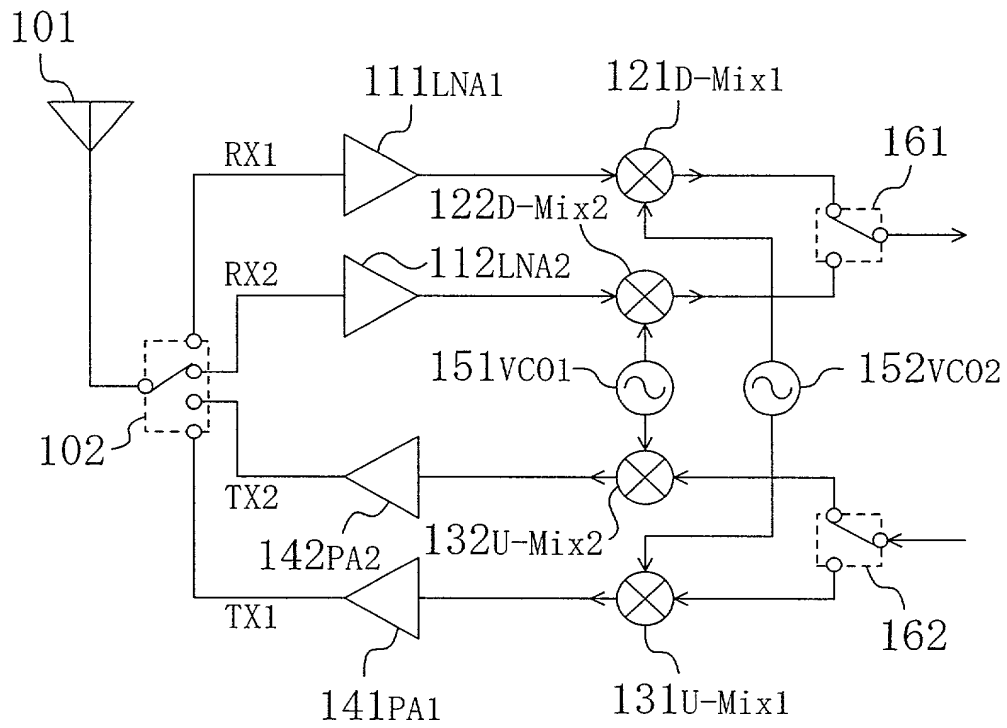
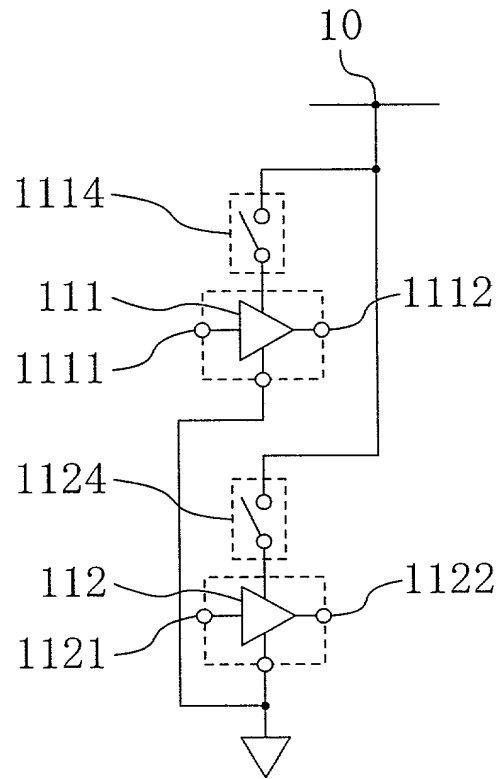


Fig. 32



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Fig. 33



COMBINED DECLARATION FOR PATENT APPLICATION AND POWER OF ATTORNEY

(Includes Reference to PCT International Applications)

Attorney Docket No:

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PRIOR U.S. APPLICATIONS OR PCT INTERNATIONAL APPLICATIONS DESIGNATING THE U.S. FOR BENEFIT UNDER 35 U.S.C. 120:**U.S. APPLICATIONS****STATUS (Check one)**

U.S. APPLICATION NUMBER

U.S. FILING DATE

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PENDING

ABANDONED

PCT APPLICATIONS DESIGNATING THE U.S.

PCT APPLICATION NO.

PCT FILING DATE

U.S. SERIAL NUMBERS
ASSIGNED (if any)

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. (*List name and registration number*)

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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COMBINED DECLARATION FOR PATENT APPLICATION AND POWER OF ATTORNEY
 (Includes Reference to PCT International Applications)

Attorney Docket No

As a below named inventor, I hereby declare that:

My residence post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

SEMICONDUCTOR APPARATUS AND COMMUNICATION APPARATUS

the specification of which (check only one item below):

☐ is attached hereto.

☐ was filed as United States application

Serial No.

on

and was amended

on _____ (if applicable).

☒ was filed as PCT international application

Number **PCT/IP00/01521**

on **March 14, 2000**

and was amended under PCT Article 19

on _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations. § 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent or inventor's certificate or of any PCT international applications(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed:

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COUNTRY	APPLICATION NUMBER	DATE OF FILING (day, month, year)	PRIORITY CLAIMED UNDER 35 USC 119
JAPAN	11-068252	15/03/1999	<input checked="" type="checkbox"/> YES <input type="checkbox"/> NO
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			<input type="checkbox"/> YES <input type="checkbox"/> NO
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